SOIL-GEOMORPHIC AND PALEOCLIMATIC CHARACTERISTICS OF THE FORT BLISS MANEUVER AREAS, SOUTHERN NEW MEXICO AND WESTERN TEXAS

By
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Historic and Natural Resources Report No. 10
Cultural Resources Management Program
Directorate of Environment
United States Army Air Defense Artillery Center
Fort Bliss, Texas

1993

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY AIR DEFENSE ARTILLERY CENTER AND FORT BLISS
FORT BLISS, TEXAS 79916-0058

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ATTENTION OF

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Glen DeGarmo, Ph.D.
Archaeologist

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H. Curtis Monger

FOREWORD

This report describes the results of a study of the geomorphological and paleoclimatic variability documented in the maneuver areas on Fort Bliss. It was mentioned in the Foreword to Dr. Michael Foster's *Pueblo Sin Casas (FB6273), A Multicomponent Site in the Hueco Bolson, Fort Bliss, Texas,* Report Number 7 in this series.

The identification and mapping of stable land surfaces in some areas of the post is of considerable interest to the Cultural Resources Management Program on Fort Bliss. Evidence of some subsets of activities conducted during most of the archaeological periods that comprise the archaeological record on the installation may lie exposed on these surfaces.

Identification of other areas where prehistoric occupational surfaces may be buried confirms the general finding that sites in some areas are visible only in road beds lower than the surrounding surface of the land upon which no archaeological materials are visible. Knowledge of the probable extent and age of the surfaces will be very useful in future years.

The identification of multiple episodes of eolian deflation and deposition adds to the complexity of the problems of attempting to interpret surface evidences of the archaeological record on the post. A project currently being conducted by Dr. Monger is concentrated upon dating and mapping the evidence of these episodes. It is anticipated that the results of this work will be useful for attempts to understand the chronological relationships between sites exposed upon these eolian surfaces and the stratigraphy of sites in locations where episodes of deposition and deflation are preserved.

The documentation of a major deflational and climatic event that occurred sometime between 10,000 and 7,000 years ago is of considerable importance. The event, now documented with additional data from Fort Bliss, appears to be one that occurred throughout the Southwest. It probably caused considerable damage to the archaeological record that existed prior to the event. As suggested in Chapter XII of this report, it may be very difficult to find intact Paleo-Indian and early Archaic sites on Fort Bliss. One of the questions being investigated by the current study of eolian phenomena on Fort Bliss is whether there are areas on the post where these early parts of the archaeological record still remain.

GLEN DEGARMO, PH.D.
Cultural Resources Management Program
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ABSTRACT

Soil-Geomorphic Characteristics

By the early Quaternary period (2 million years ago) the ancestral Rio Grande had spilled through Fillmore Pass between the Organ and Franklin Mountains and was filling the Hueco Bolson with river sediments (Hawley et al., 1969). By middle Pleistocene, when the ancestral Rio Grande entrenched into its modern valley (400 to 300 ka, Gile et al., 1981), it had been diverted back to the west of the Franklin Mountains, probably as the result of uplifting of the Organ-Franklin Mountain chain (Seager 1981). Since the mid-Pleistocene, landscape evolution on Fort Bliss has been restricted mainly to (1) alluvial fan deposition, (2) land displacement along faults, and (3) eolian activity.

Alluvial fan deposition has involved at least four generations of alluvial fans on the piedmont aprons that skirt the mountains. The fans range in age from approximately 400 ka to the present arroyo mouth deposits. Land displacement along faults has occurred throughout the late Pleistocene and Holocene. Sediments that fill linear depressions caused by extensional faulting are the result of both tectonic movement and climatically driven sedimentation that presumably corresponds to periods of aridity. Eolian activity has modified existing soil strata in areas that were not sheltered from wind erosion by desert pavement, vegetation, or younger deposits. Most of the soilscape on Fort Bliss has experienced multiple periods of deflation and reburial by locally derived eolian sediments. There are at least four eolian deposits in the basin floor that range in age from early Holocene to Historical blowsand deposits.

Late Quaternary Climatic and Environmental Conditions

Based on $\delta^{18}O$ in soil carbonates, the mean annual temperature appears to have been only slightly cooler during the late Pleistocene than the Holocene. A major shift toward aridity, however, occurred between 9 and 7 ka, based on four lines of evidence: (1) By 7 ka the latest generation of alluvial fans (the Organ alluvium) began to be deposited. The onset of this erosion-sedimentation event appears to have been triggered by the decline of vegetation in response to aridity. (2) The $\delta^{13}C$ in soil carbonates on the fan-piedmont area of the Organ Mountains shifts toward lower values at approximately 8 ka. This shift implies a change from C-4 grassland to C-3 desert scrub. (3) Fossil pollen analysis from a site in the same fan-piedmont area reveals a decline in grassland pollen and an increase in Cheno-am pollen during the same early-Holocene period. (4) At several locations in the basin floor area of Fort Bliss, pedogenic carbonate nodules and Rio Grande pebbles are concentrated into a layer that appears to be a paleo-deflational surface similar to deflational surfaces on Fort Bliss today. Inorganic radiocarbon dates of lag nodules indicate the deflational event occurred after 10 ka. Radiocarbon dates of hearths confirm that the event occurred before 4 ka and probably happened prior to 7 ka, based on radiocarbon dates of soil calcite. This desertification event is presumed to correspond to the onset of Organ sedimentation as well as the isotope and pollen changes that occurred approximately 8 ka.

Chapter I

INTRODUCTION

The purpose of this study was to describe and interpret soil-geomorphic features on Fort Bliss in southern New Mexico and western Texas in order to obtain information about landscape evolution and paleoclimatic conditions during the late Quaternary. This information is intended to assist Fort Bliss archaeologists in evaluating archaeological site locations and conditions in terms of their geomorphic and paleoclimatic context. To obtain this goal, backhoe trenches were dug and maps were made of the geomorphic surfaces and deflated depositional areas. In addition to soil-geomorphic evidence of paleoclimatic and environmental conditions, stable isotopes, fossil pollen, and phytoliths were examined (see Figure I-1).

An area on McGregor Range in the vicinity of Benton Well was investigated to determine if the area was occupied by a late Pleistocene pluvial lake. If so, the lake might have been significant to the possible late Pleistocene inhabitants of Pendejo Cave and would provide further paleoclimatic information about the late Pleistocene-early Holocene time period. Quaternary ages in this report are based on the assigned dates in Table I-1.

Table I-1. Quaternary Ages (after Gile et al. 1981)

Period or System	Epoch or Series	Thousands of Years Ago (ka)
Quaternary	Historical	1850 A.D. to present
	Holocene	late 2.5 to present mid 2.5 to 7.5 early 7.5 to 10
	Pleistocene	late 10 to 250 mid 250 to 900 early 900 to 2000

Twenty-four sites, in the forms of backhoe trenches, hand-dug pits, and natural exposures, were studied on Fort Bliss North (see Figure I-2), and sixteen sites were studied on Fort Bliss South (see Figure I-3). The gathered data included radiocarbon dates, stable isotopes, fossil pollen, phytoliths, particle size analysis, organic carbon (OC), calcium carbonate, and thin sections (see tables I-2 and I-3).

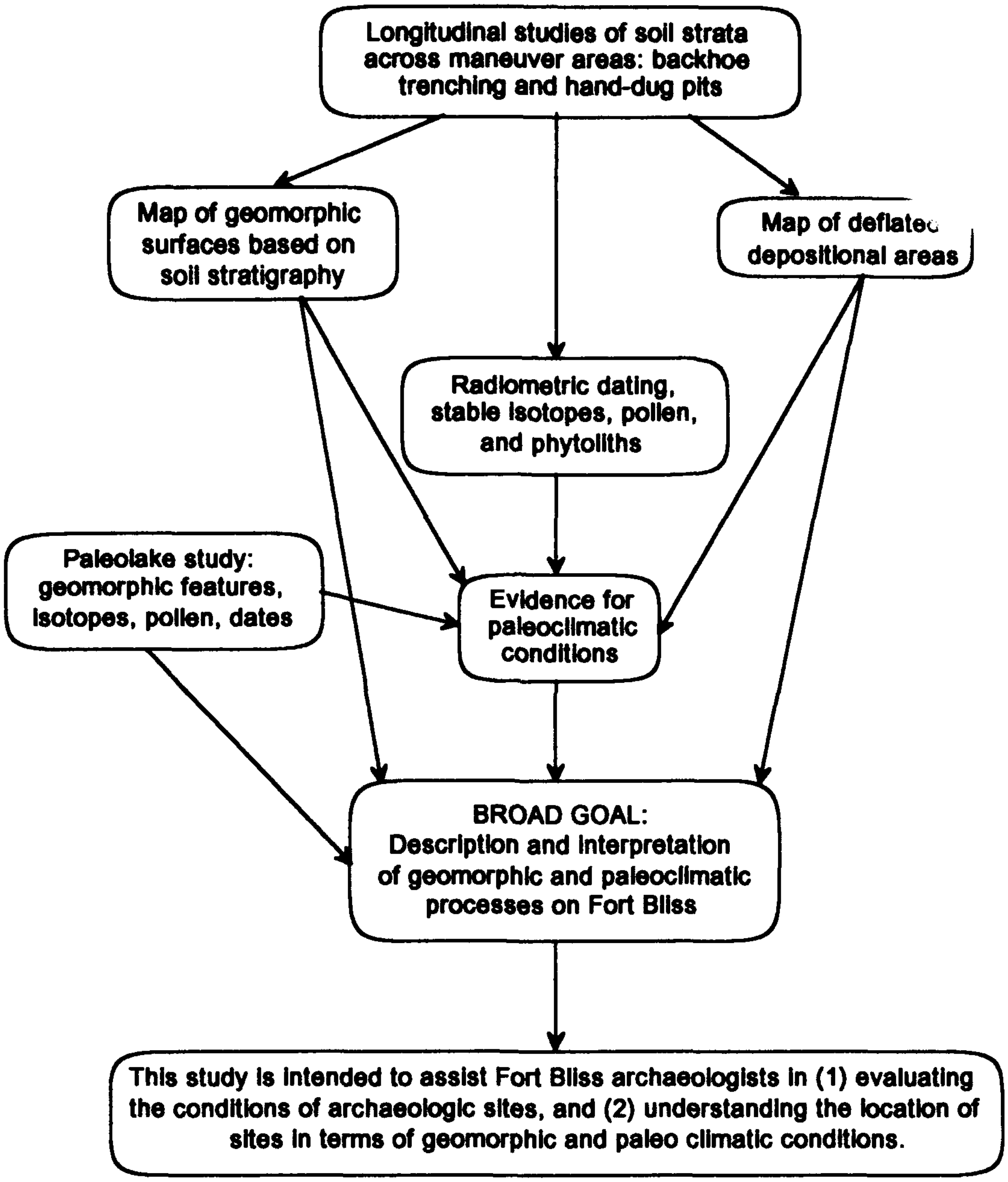


Figure I-1. Fort Bliss Soil-Geomorphic and Paleoclimatic Study Plan

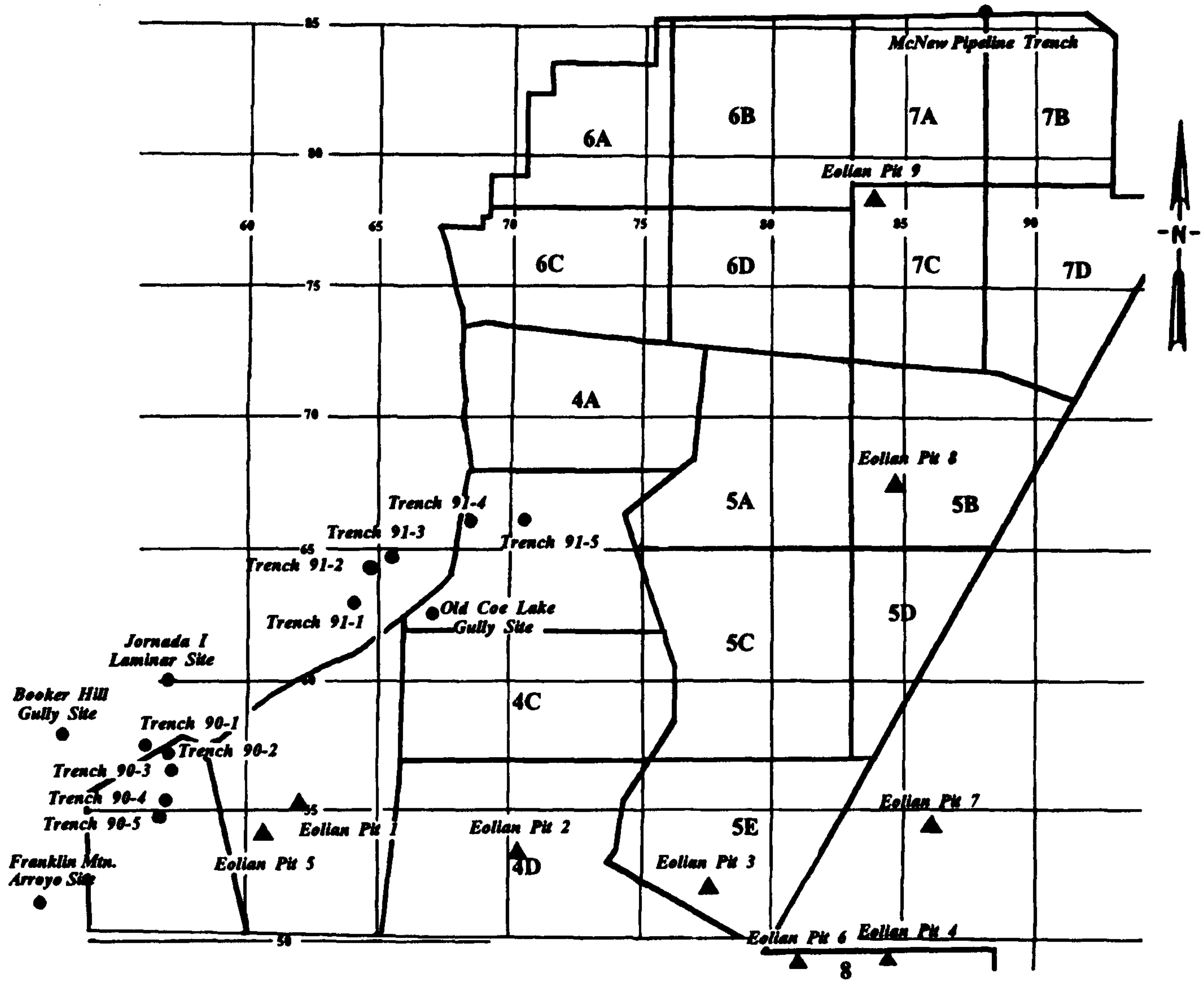


Figure I-2. Study sites and Maneuver Areas on Fort Bliss North

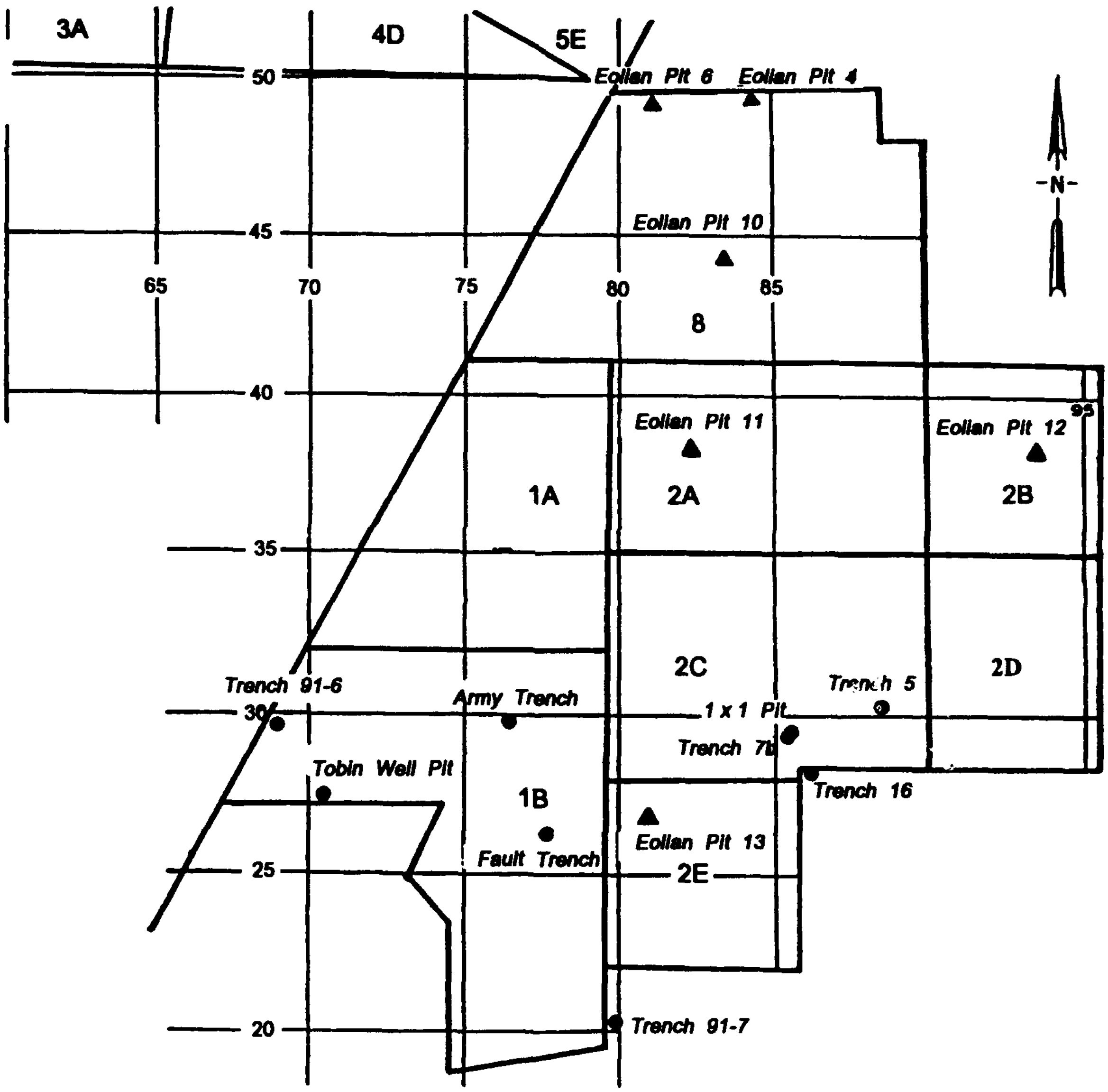


Figure I-3. Study Sites and Maneuver Areas on Fort Bliss South

Table I-2. Data Collected at Study Sites on Fort Bliss North

Site	UTM Location	C-14	Stable Isotopes	Pollen	Phytoliths	Percent S, Si, C.	Sand Fractionation	Percent Coarse Fragments	Percent O.C.	Percent $CaCO_3$	Profile Description
Trench 90-1	559574	X	X	X		X	X	X	X	X	X
Trench 90-2	565571					X	X	X	X	X	X
Trench 90-3	568566					X	X	X	X	X	X
Trench 90-4	564555					X	X	X	X	X	X
Trench 90-5	565545					X	X	X	X	X	X
Trench 91-1	641634	X	X			X	X	X	X	X	X
Trench 91-2	648644										
Trench 91-3	634649					X	X	X	X	X	X
Trench 91-4	688659					X	X	X	X	X	X
Trench 91-5	703660					X	X	X	X	X	X
McNew Pipeline Trench	880858										
Old Coe Lake Gully Site	667625	X	X	X	X	X	X	X	X	X	X
Jornada I Laminar Site	601572	X	X								
Booker Hill Gully Site	530580	X	X	X	X	X	X	X	X	X	X
Franklin Mt. Arroyo Site	520513		X	X							
Eolian Pit 1	626551					X	X	X		X	X
Eolian Pit 2	705534					X	X	X		X	X
Eolian Pit 3	772521					X	X	X		X	X
Eolian Pit 4	845495					X	X	X		X	X
Eolian Pit 5	604538					X	X	X		X	X
Eolian Pit 6	808493					X	X	X		X	X
Eolian Pit 7	861544					X	X	X		X	X
Eolian Pit 8	849675					X	X	X		X	X
Eolian Pit 9	839795					X	X	X		X	X

Table I-3. Data Collected at Study Sites on Fort Bliss South

Site	UTM Location	C-14	Stable Isotopes	Pollen	Phytoliths	Percent S, Si, C.	Sand Fractionation	Percent Coarse Fragments	Percent O.C.	Percent $CaCO_3$	Profile Description
Trench 91-6	691299					X	X	X		X	X
Trench 91-7a	799205					X	X	X	X	X	X
Trench 91-7b	799205					X	X	X	X	X	X
Trench 5	881302	X	X			X	X		X	X	X
Trench 7b N	885295	X	X			X	X		X	X	X
Trench 7b M	855295					X	X		X	X	X
Trench 7b S	855295					X	X		X	X	X
Trench 16	863284	X	X	X							
1x1 Pit	855296	X	X								X
Fault Trench	775261			X	X						
Army Trench	767299	X	X								X
Tobin Well Pit	704274	X	X								X
Eolian Pit 10	831441					X	X			X	X
Eolian Pit 11	823385					X	X			X	X
Eolian Pit 12	935384					X	X			X	X
Eolian Pit 13	809267					X	X				X

Chapter II

METHODS

Mapping

Maps of geomorphic surfaces and eolian alteration were made using a combination of aerial photography and field identification. Geomorphic surfaces were identified by soil development and their geomorphic position (see Chapter III). Eolian alteration maps were based on vegetative clues, such as the occurrence of coppice dunes and grasslands, in addition to augering, digging backhoe trenches, and systematically driving roads and perusing aerial photographs looking for exhumed, indurated caliche fragments (see Chapter IV).

Stereo-pair aerial photographs were used to identify three dimensional topographic features. The photographs were 1984 United States Geological Survey (USGS) high-altitude program (HAP) color-infrared, scale 1:58,000. The 1:50,000 Fort Bliss North and South topographic maps were used as base maps. Mapping unit delineations were drawn on transparent overlays covering the aerial photographs. These lines were transferred to the 1:50,000 base maps, which were photocopied in sections.

Soil Characterization

The step-by-step procedure for analyzing soil organic carbon and particle size distribution is given below. Analysis of calcium carbonate follows the procedure described in Soil Survey Staff (1982).

Bulk Sample Preparation

1. Air dry soil sample approximately two days.
2. Crush with wooden rolling pin and weigh whole soil sample.
3. Sieve with 2-mm sieve to separate coarse fragments.
4. Weigh coarse fragments and calculate their percentages.

Organic Carbon (after Nelson and Sommers 1982)

1. Sieve the < 2-mm soil with a 0.5-mm sieve.
2. Weigh 1 g of sieved soil into a 400-mL beaker or Erlenmeyer flask.
3. Add 10 mL of 1*N* $K_2Cr_2O_7$ and swirl. (Prepare $K_2Cr_2O_7$ solution by dissolving 49.04 g of reagent-grade $K_2Cr_2O_7$ in 1000 mL of water.)
4. Add 20 mL of conc H_2SO_4, mix by swirling, then let cool.
5. Add 200 mL of water (filter suspension if experience shows that titration endpoint cannot be clearly discerned otherwise.)
6. Add 2-3 drops of o-phenanthroline indicator.
7. Titrate the solution with 0.5 *N* $FeSO_4$. (Prepare $FeSO_4$ solution by dissolving 140 g of reagent, add 15 mL of conc sulfuric acid, cool, dilute to 1000 mL.)
8. As endpoint approaches, the solution becomes green then blue. At this point, titrate drop by drop until the color changes from blue to maroon.
9. Calculate results according to the following formula:

$$\text{Organic Carbon} = \frac{(\text{meq } K_2Cr_2O_7 - \text{meq } FeSO_4)(0.003)(100)(1.30)}{\text{g air dry soil}}$$

Particle Size Analysis (after Gee and Bauder 1986)

1. Add between 40 to 80 g of < 2-mm soil to 250-mL Pyrex centrifuge bottle (sandy soils require more sample than clayey soils). Add 100 mL of water.
2. **Remove carbonates** by adding I *M* HCl dropwise with stirring until pH 3.5 or 4.0, leave sample overnight and recheck pH, adding more acid if necessary (Jackson 1956).
3. Wash sample by centrifuging at 1500 rpm for 10 min and decanting clear supernatant until sample is near neutral pH.
4. **Remove organic matter** by adding 25 mL H_2O_2. Heat sample on hot plate to increase reaction rate. Continue to add H_2O_2 until frothing is minimal.
5. Wash sample by centrifugation and decanting clear supernatant.
6. Transfer sample to 1000-mL sedimentation cylinder. Add 100 mL of 5-percent sodium hexametaphosphate, plunge and let soak over night.
7. Plunge sample several times and take readings at
   - 30 seconds
   - 60 seconds
   - 1.5 hour
   - 24 hours
8. Determine oven-dry sample weight by transferring sample into pre-weighed oven bags, and drying at 105° C until dry. Let sample cool and equilibrate with ambient moisture, which is reached when the weight becomes constant. Record weight.

Isotope Analysis

All samples used for isotope analysis were taken from freshly excavated profiles. Pedogenic carbonate, which is generally composed of calcite crystals 1 to 5 μm in diameter (Monger et al. 1991), were concentrated by sieving with a 53 μm sieve. Stable isotope measurements were carried out by converting pedogenic calcite to CO_2 liberated by reacting the sieved soil samples with 100% phosphoric acid. Results are reported in the (per mil) notation where

$$\delta = [(R_{sample}/R_{standard})-1]\ 1000$$

and R_{sample} and $R_{standard}$ refer to the $^{13}C/^{12}C$ or $^{18}O/^{16}O$ ratio in a sample and standard, respectively. The δ values are generally reproducible to ±0.1 for carbon and ±0.2 for oxygen.

Stage I carbonate filaments from the 1x1 pit (UTM 855296, Fig. 3) were concentrated by microscopically siphoning the filaments into a flask of deionized water. Approximately 100 grams of the carbonate-rich material were oven dried and sent to Beta Analytic, Inc., for inorganic radiocarbon dating and stable isotope analysis.

Part I

SOIL-GEOMORPHIC CHARACTERISTICS

Chapter III

GEOMORPHIC SURFACES OF MANEUVER AND ADJACENT AREAS OF FORT BLISS

By H. Curtis Monger

General Landforms

Six major landforms were delineated within the study area of Fort Bliss North and South (see figures III-1 and III-2).

The *La Mesa Basin floor* occupies the Hueco Bolson. The upper portion of this basin fill deposit comprises the Camp Rice Formation of Strain (1966) which is the upper subdivision of the Santa Fe Group (Hawley et al. 1969). The La Mesa geomorphic surface is the constructional top of the Camp Rice Formation and is of early to middle Pleistocene age (Gile et al. 1981).

The sediment apron surrounding mountains in the study area makes up the *fan-piedmont* landform. The fan-piedmont landform is composed of alluvial fans, interfan valleys, and coalescent fans (bajadas).

Within the La Mesa Basin floor are younger deposits occupying depressions (Seager et al. 1987). In this study, these deposits are referred to as *youngest basin fill.* These deposits are associated with the Petts Tank and Lake Tank geomorphic surfaces of Gile et al. (1981).

The *bedrock landform* occurs in the upper Organ, Jarilla, Franklin, and Hueco mountain areas not covered with quaternary sediments. This landform is composed of various igneous and sedimentary rocks with minor amounts of metamorphic rocks (cd Hardie 1958; Harbour 1972; Seager 1981; Kelly and Matheny 1983; and Seager et al. 1987).

Although most of the study area, especially the basin floor, is covered with coppice dunes and eolian sheet deposits, a few areas are covered with enough deep eolian sediments to merit delineation as a separate landform. These areas of deep sand (several meters) and sparse interdune areas were designated the *dunes* landform.

The *fault complex* landform is composed of fault scarps, associated linear basins, and downthrown blocks. Soils associated with the fault complex vary in age, thickness, and pedogenic development. Eroded soils, which are often buried by Historical eolian sediments, are common on the scarps. Sequences of buried soils are common in the trough-shaped basins.

Geomorphic Surfaces

Geomorphic surfaces contain evidence of landscape evolution that, on Fort Bliss, has been driven primarily by climate change during the Holocene and late Pleistocene. Geomorphic surfaces are landform surfaces defined in terms of geologic age and pedologic development (Gile et al. 1981). A geomorphic surface is a mappable landscape element formed during a discrete time period and has distinctive materials,

topographic features, soil profiles, and weathering characteristics (Bull 1991). A single geomorphic surfaces can be composed of both erosional and constructional (depositional) phases (Daniels and Hammer 1992).

The fan-piedmont landform southeast of the Organ Mountains (see Figure III-1) contains examples of geomorphic surface application. A portion of this landform is subdivided into four geomorphic surfaces based on alluvial fan deposit ages. Geomorphic surface ages are indicated by the degree of pedogenic development (see Figure III-3).

Names of geomorphic surfaces used in this study were borrowed from the neighboring Desert Project, a soil-geomorphic study conducted on a 400-square-mile area surrounding Las Cruces, New Mexico, by the United States Department of Agriculture (USDA) Soil Conservation Service (Gile and Grossman 1979). The Desert Project area was studied by a team of soil scientists and geologists from 1957 to its formal completion in 1972. Significant soil-geomorphic research, however, continues to be conducted in the Desert Project area (e.g., Gile 1987a, b; and Gile 1990).

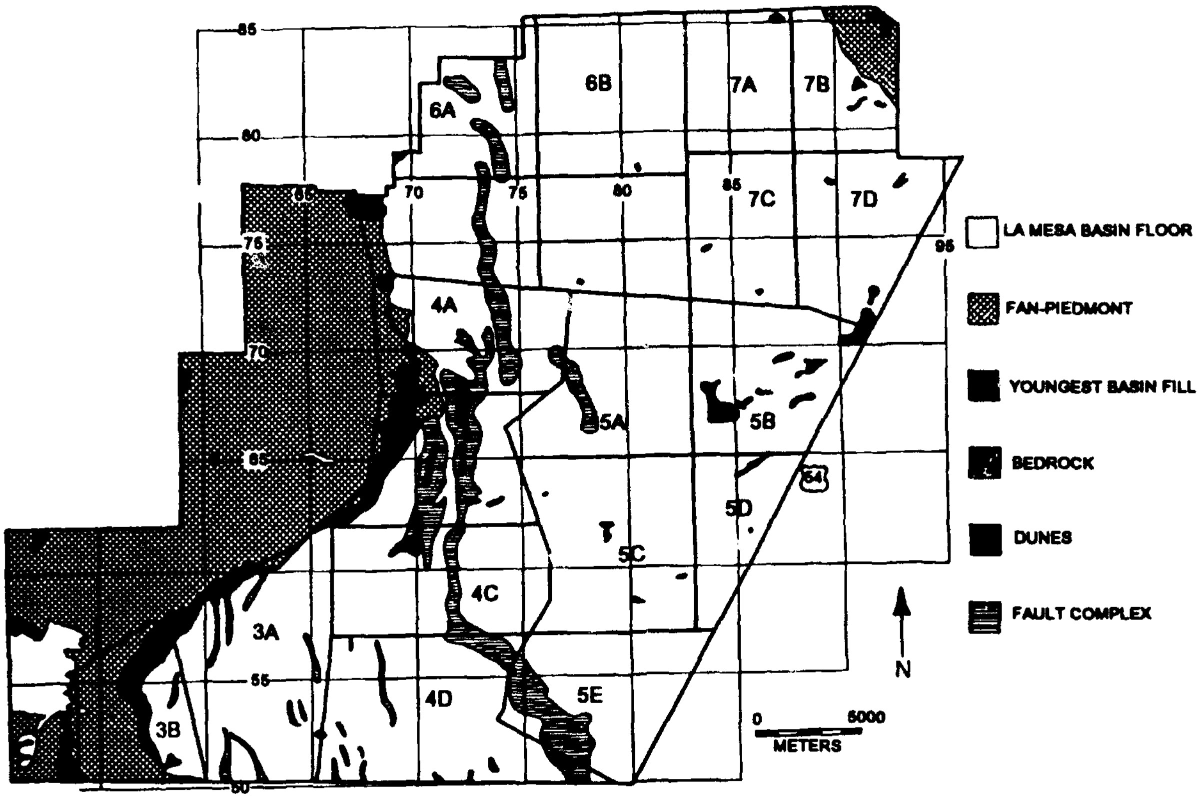


Figure III-1. General Landforms of Fort Bliss North

La Mesa (basin floor deposits of early to middle Pleistocene age)

The La Mesa geomorphic surface, which occupies most of the basin floor, is the most extensive geomorphic surface in the Fort Bliss study area (see figures III-4 and III-5), as well as the oldest (see Figure III-6). The La Mesa surface, which caps the Camp Rice fluvial facies (Gile et al. 1981; Seager et al. 1987), can be identified by its stage IV carbonate morphogenic sequence of Gile et al. (1966) (see Figure III-7). In some areas, such as the borrow pits near McGregor Camp (UTM 865499), the soils have developed stage V morphology of Machette (1985) (see Figure III-7).

Pipeline trenches of Loop 375, under construction across the basin floor in Fort Bliss South, revealed La Mesa also could have stage III. These deep trenches penetrated down through the La Mesa soil into the pedogenically unmodified layers of Camp Rice clays, sands, and mixed-rounded gravels. Stage III La Mesa appears to reflect an absence of late Quaternary erosion (Gile, personal communication 1992). Perhaps in order to form laminar layers atop the carbonate-plugged horizon, the plugged horizon must be brought to shallow depths. A plugged horizon at shallow depths would impede wetting fronts, causing them to flow laterally across the top of the plugged horizon and produce laminar morphology.

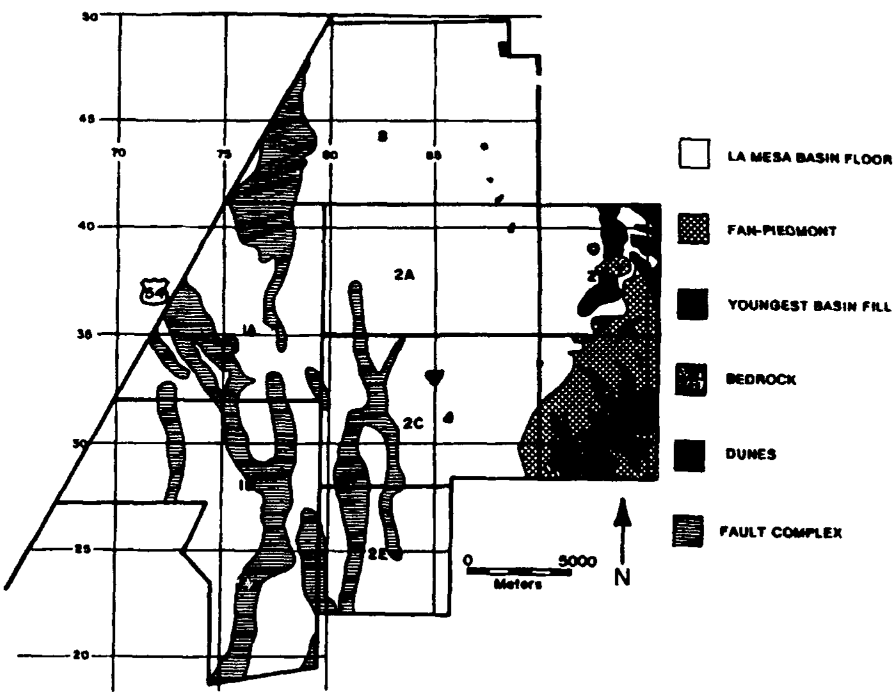


Figure III-2. General Landforms of Fort Bliss South

The most distinctive feature of the Camp Rice fluvial facies is the well-rounded pebbles of quartz, chert, quartzite, and other siliceous rock fragments (Seager 1981). The La Mesa soil profile above the indurated caliche (petrocalcic horizon or calcrete) has experienced various degrees of erosion and reburial by eolian sediments (see Chapter IV). The La Mesa surface is generally level, having slopes of less than 1 percent.

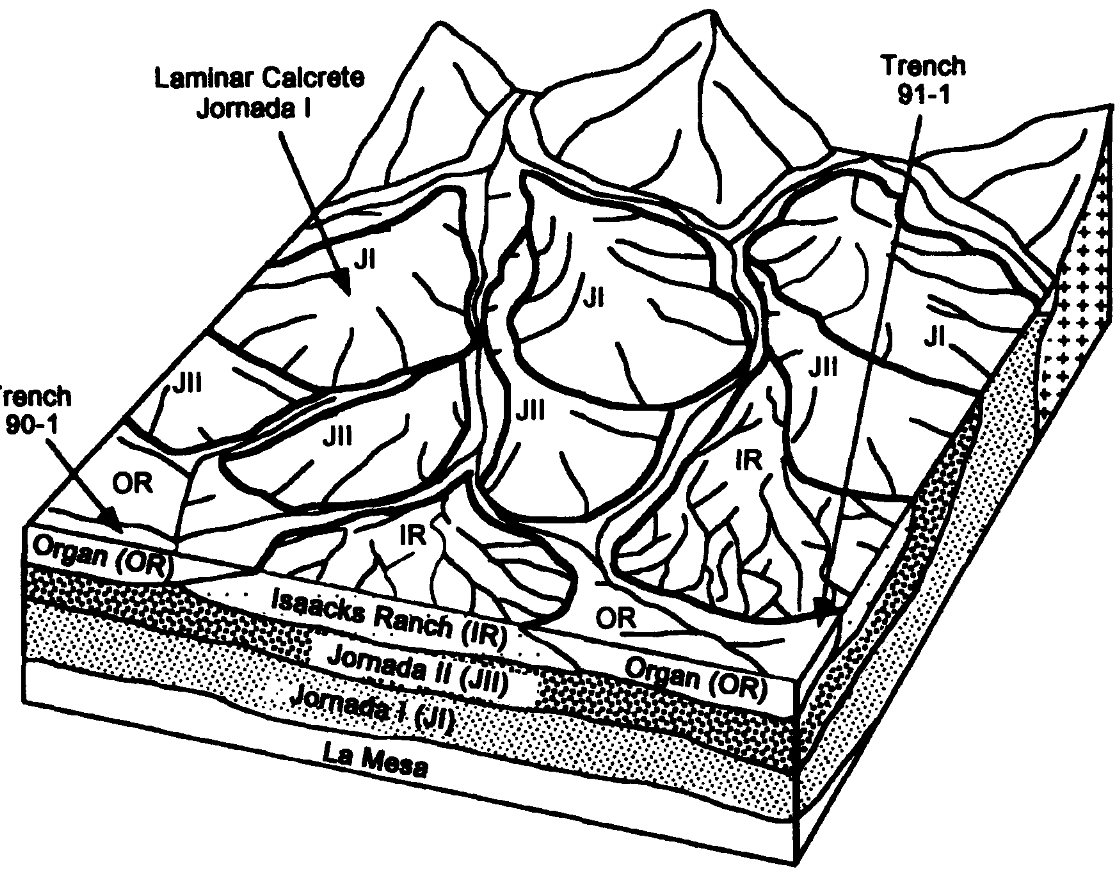


Figure III-3. Alluvial fan deposits that comprise a portion of the fan-piedmont landform in the area southeast of the Organ Mountains. Older geomorphic surfaces, such as the Jornada I surface, have associated soils with advanced pedogenic development (e.g., indurated caliche). In contrast, soils associated with younger geomorphic surfaces, such as the Organ surface, exhibit weaker pedogenic development (e.g., stage I carbonate filaments of Gile et al. 1966).

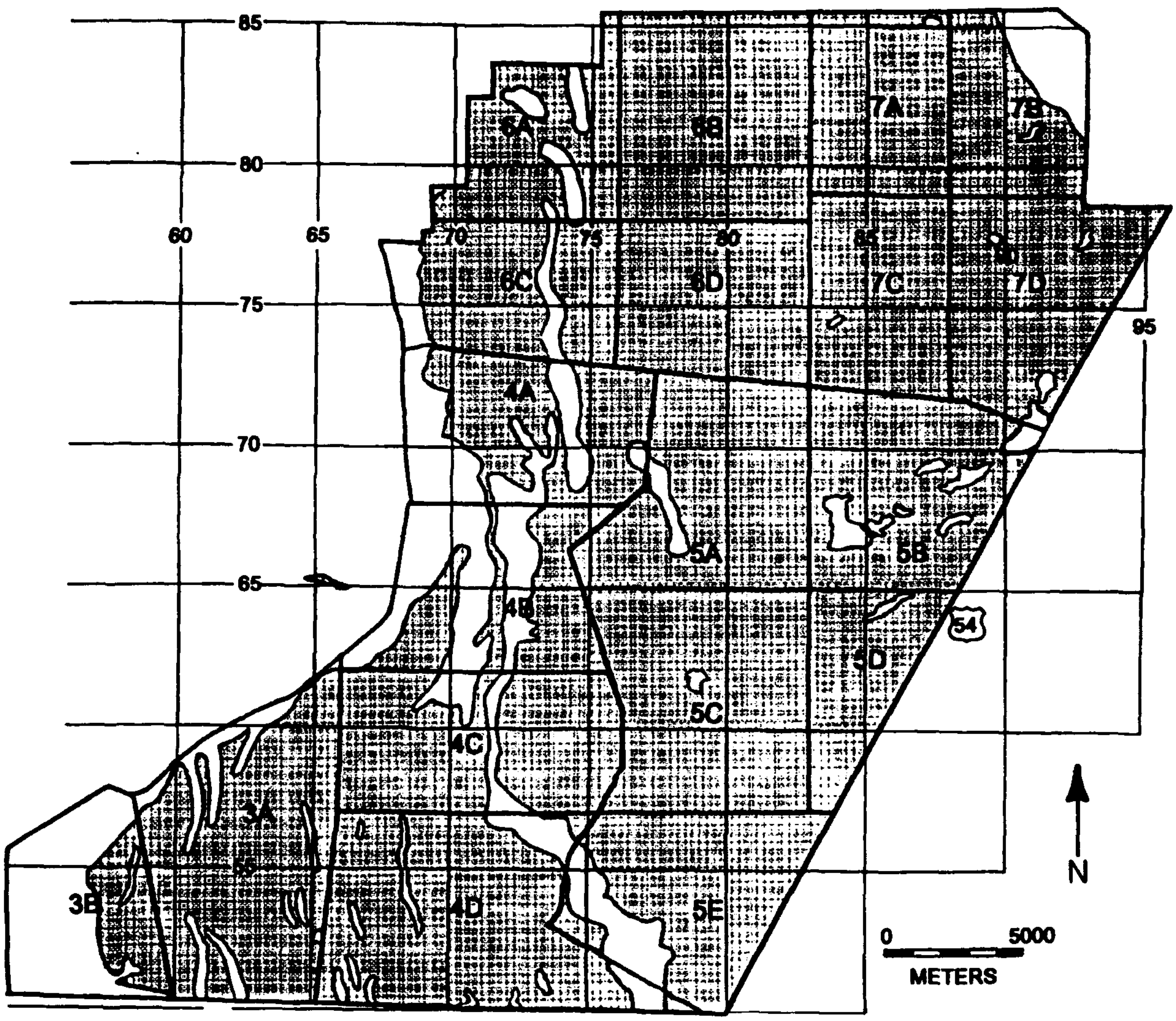


Figure III-4. La Mesa Geomorphic Surface Distribution (shaded area) on Fort Bliss North

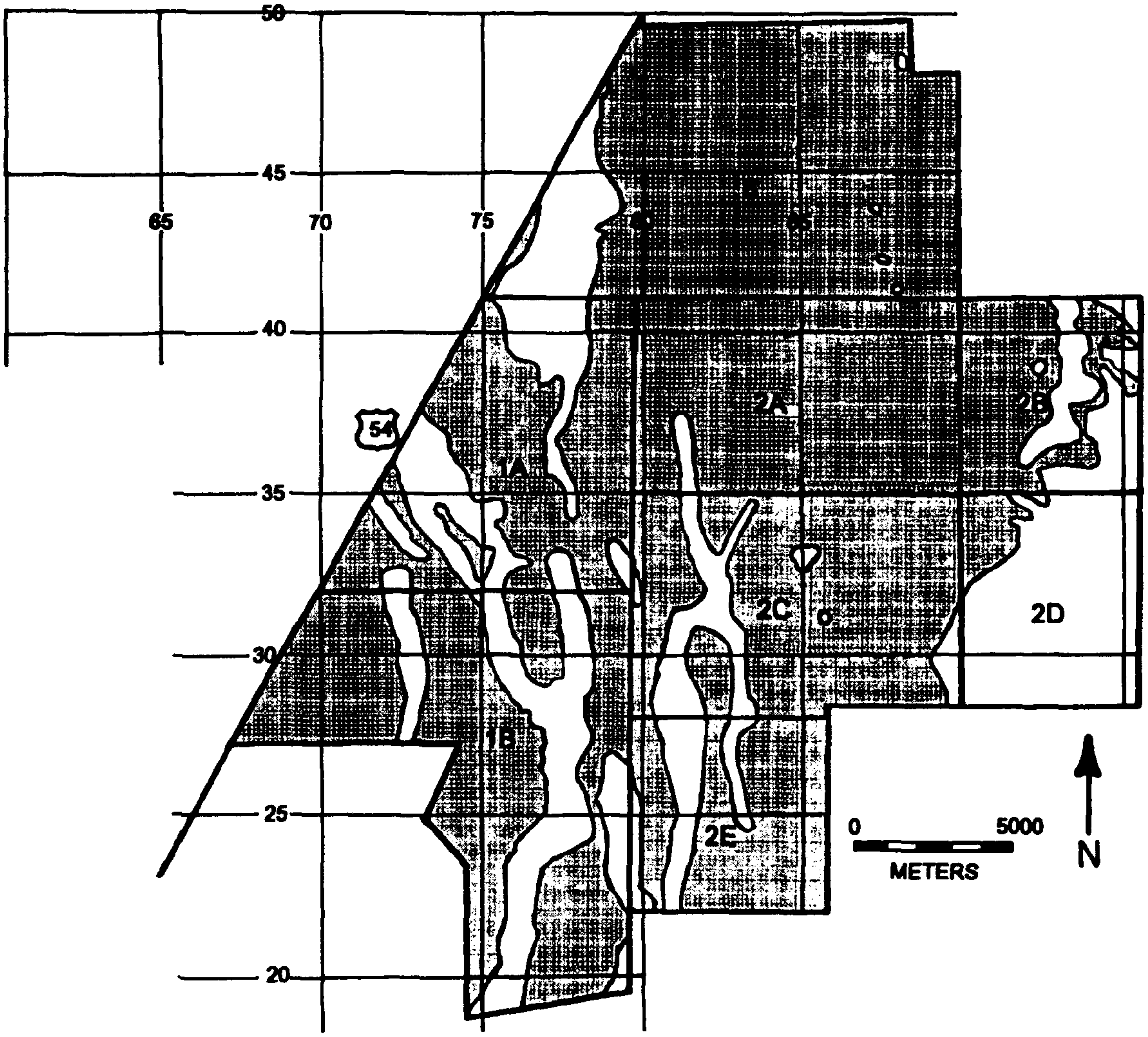
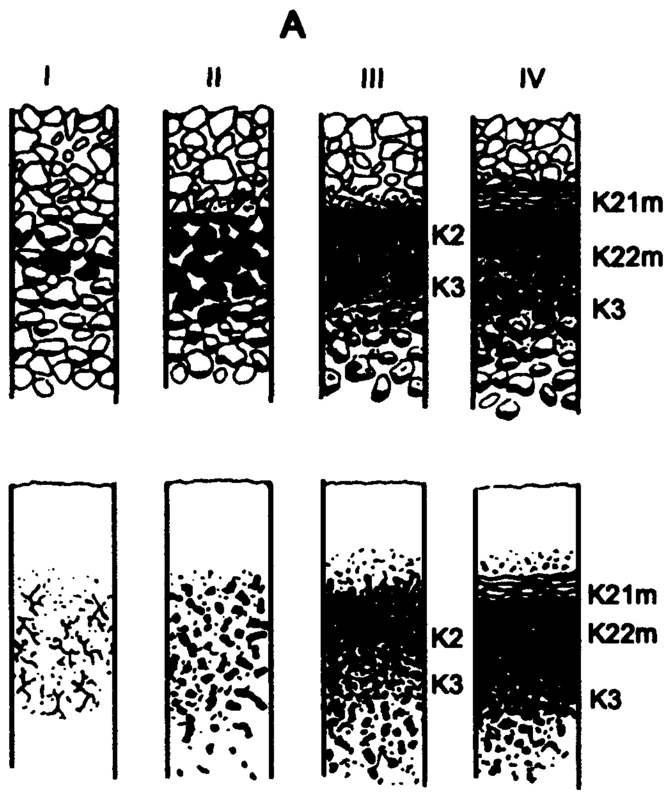


Figure III-5. La Mesa Geomorphic Surface Distribution (shaded areas) on Fort Bliss South

EPOCH	Fort Bliss Stratigraphy	Age (10^3 years)		
		Soil Carbonate	Radiometric	
Holocene	Organ III	6-10[a]	0.1-1.1 (C-14)[c]	
	Organ II		1.1-2.1 (C-14)[c]	
	Organ I		2.2-7 (C-14)[c]	
Late Pleistocene	Isaacks Ranch	8-15[b]	9.5 (C-14)[d]	
		25-31[a]	22 ±15 (UT)[a]	
	Jornada II (young phase)	62[a]		**REFERENCES**
	Jornada II	95[a]	130 ±20 (UT)[a]	(a) Machette, 1985
	(main phase)		180? (K-Ar)[a]	(b) Gile, 1987
Middle Pleistocene	Jornada I (young phase)	306[a]		(c) Gile et al., 1981
			290 ±20 (UT)[a]	(d) Blair et al., 1990
	Jornada I (old phase)	388[a]		(e) Izett and Wilcox, 1982
	La Mesa	500[a]		(f) Hawley et al., 1969
			620 (K-Ar)[e, f, g]	(g) Seager et al., 1975

Figure III-6. Geomorphic Surface Ages and Associated Deposits on Fort Bliss



Stage and General Character	Diagnostic Carbonate Morphology: Gravelly Soil	Diagnostic Carbonate Morphology: Nongravelly Soil
I Weakest expression of macroscopic carbonate	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II Carbonate segregations separated by low-carbonate material	Continuous pebble coatings, some interpebble fillings	Few to common nodules
III Carbonate essentially continuous; plugged horizon forms in last part	Many interpebble fillings	Many nodules and internodular fillings
IV Laminar horizon develops	Laminar horizon overlying plugged horizon	
V Thick laminae (>1 cm) and thin to thick pisolites. Vertical faces and fractures are coated with laminated carbonate (case-hardened surface).		

Figure III-7. Soil carbonate morphogenetic sequences of Gile et al. (1966) and Machette (1985). (a) Schematic diagram of the diagnostic morphology of stages I to IV in gravelly and nongravelly material. (b) Table of morphogenetic definitions (from Gile and Grossman 1979; and Machette 1985).

Jornada I (fan deposits of late middle Pleistocene age)

Jornada I is the oldest fan-piedmont deposit in the study area (400 to 250 ka, Gile et al. 1981). The Jornada I surface occurs in the upper and middle piedmont slopes of the Organ Mountains and occupies nearly the entire piedmont areas of the Northern Franklin, Jarilla, and Hueco mountains (see Figure III-8). The Jornada I surface caps the Camp Rice piedmont facies (Gile et al. 1981). In the higher elevations of the fan-piedmont, Jornada I occupies the highest geomorphic position with younger fans inset below. Basinward, the Jornada I becomes buried by younger fans (Seager 1981).

In addition to being the geomorphically highest fans in the study area, the Jornada I surface can be identified by its well-developed soil profiles which include well-developed reddish Bt argillic horizons, if uneroded, and stage IV carbonate morphology. Jornada I also can have stage III carbonate morphology in nongravelly sediments (Gile et al. 1981). The Jornada I surface has a steeper gradient than younger fans, parallel drainage, and boulders on the surface that are more highly weathered than younger fans (Seager, 1981). Dissection of Jornada I alluvium commonly has a ridge-and-ravine (ballena) topographic pattern as described by Bull (1991).

In areas having large watersheds and sediment sources, such as the Organ Mountains, multiple alluvial fan generations can be distinguished (e.g., Jornada I and Jornada II). In contrast, multiple fan generations are absent on the fan-piedmont areas of smaller mountains, such as the Hueco Mountains. The piedmont of small mountains have a large Jornada I component, as identified by the well-developed stage IV calcrete, but younger fans probably exist also. The younger fans, however, are thin and merge with older fans, and thus are not easily discernable on aerial photographs.

Jornada II (fan deposits of late Pleistocene age)

The Jornada II surfaces occur mainly in the Organ Mountain fan-piedmont area (see Figure III-9) where they occupy an intermediate geomorphic position. The Jornada II is estimated to range in age from 150 to 25 ka (Gile 1987b). Most of Jornada II probably was deposited during the previous interglacial period (Hawley et al. 1976). Jornada II is an important surface for stable isotope (see Chapter VII) and fossil pollen (see Chapter IX) research, where it is buried by younger deposits.

The Jornada II surface is inset below the Jornada I surface and above the Isaacks' Ranch and Organ surfaces (see Figure III-3). Carbonate morphology in Jornada II can range from incipient stage IV in gravelly sediments to stage II nodules in fine-textured sediments (Gile et al. 1981). Where the soil is uneroded, it has a well-developed Bt argillic. The Jornada II, a piedmont-fan surface, grades into its basin floor equivalent, the Petts Tank surface, at the boundary between distal fans and basin floor sediments (see Figure III-10). Boulders on the Jornada II fans are less decomposed than boulders on the Jornada I fans (Seager 1981). Unlike Jornada I fans, which have parallel drainage, Jornada II fans exhibit distributary drainage characteristics.

Petts Tank (basin floor deposits of late Pleistocene age)

Petts Tank alluvium occurs in closed depression on both Fort Bliss North and South (see Figure III-11). Petts Tank is correlative with Jornada II but, in some locations, may be even older than Jornada II based on its well-developed stage III carbonate morphology in fine-grained sediments. The relationship among Petts Tank and neighboring deposits in the Doña Ana Range Camp area is illustrated in Figure III-12.

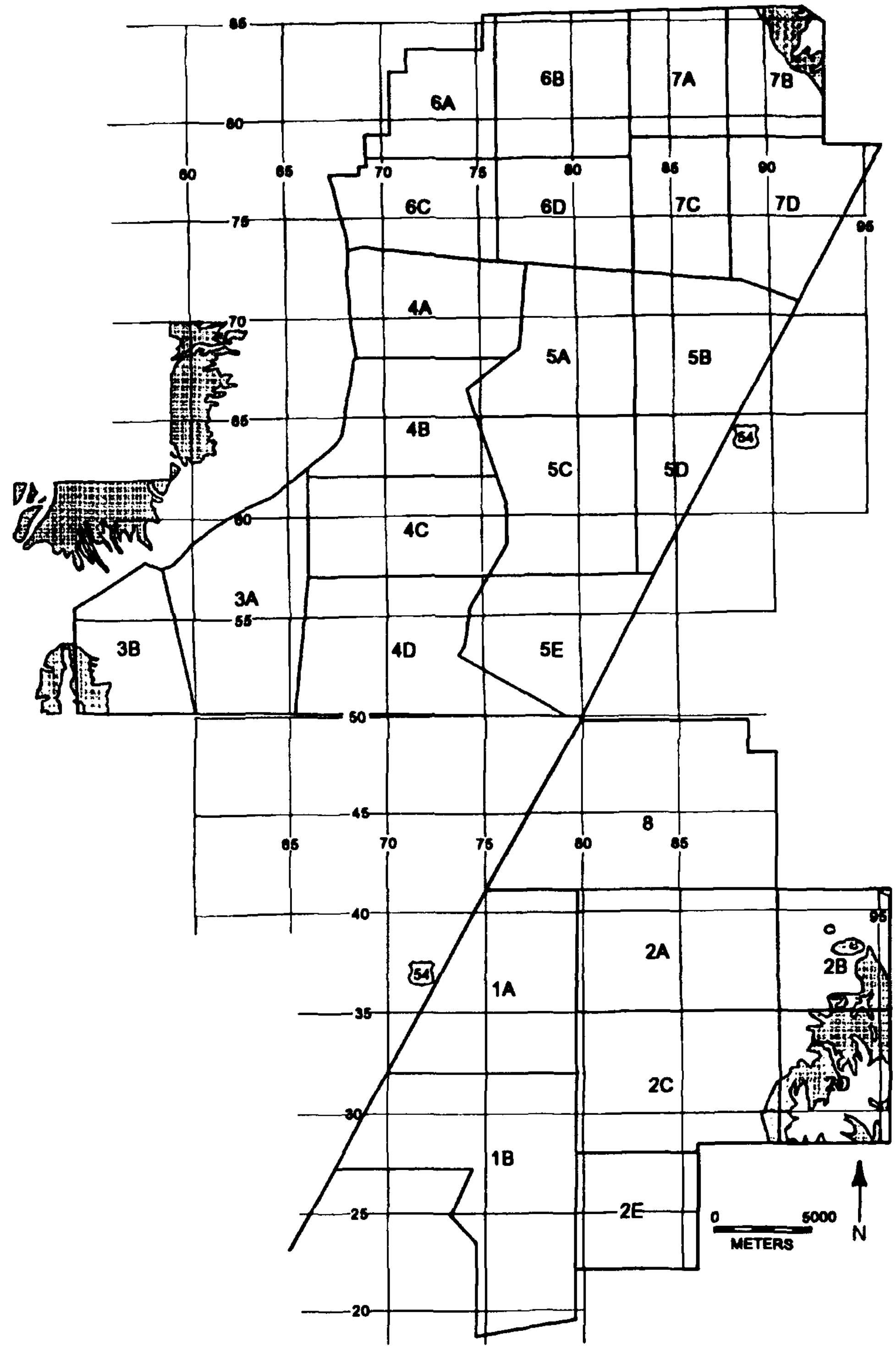


Figure III-8. Jornada I Surface Distribution (shaded areas) on Fort Bliss North (top) and Fort Bliss South (bottom)

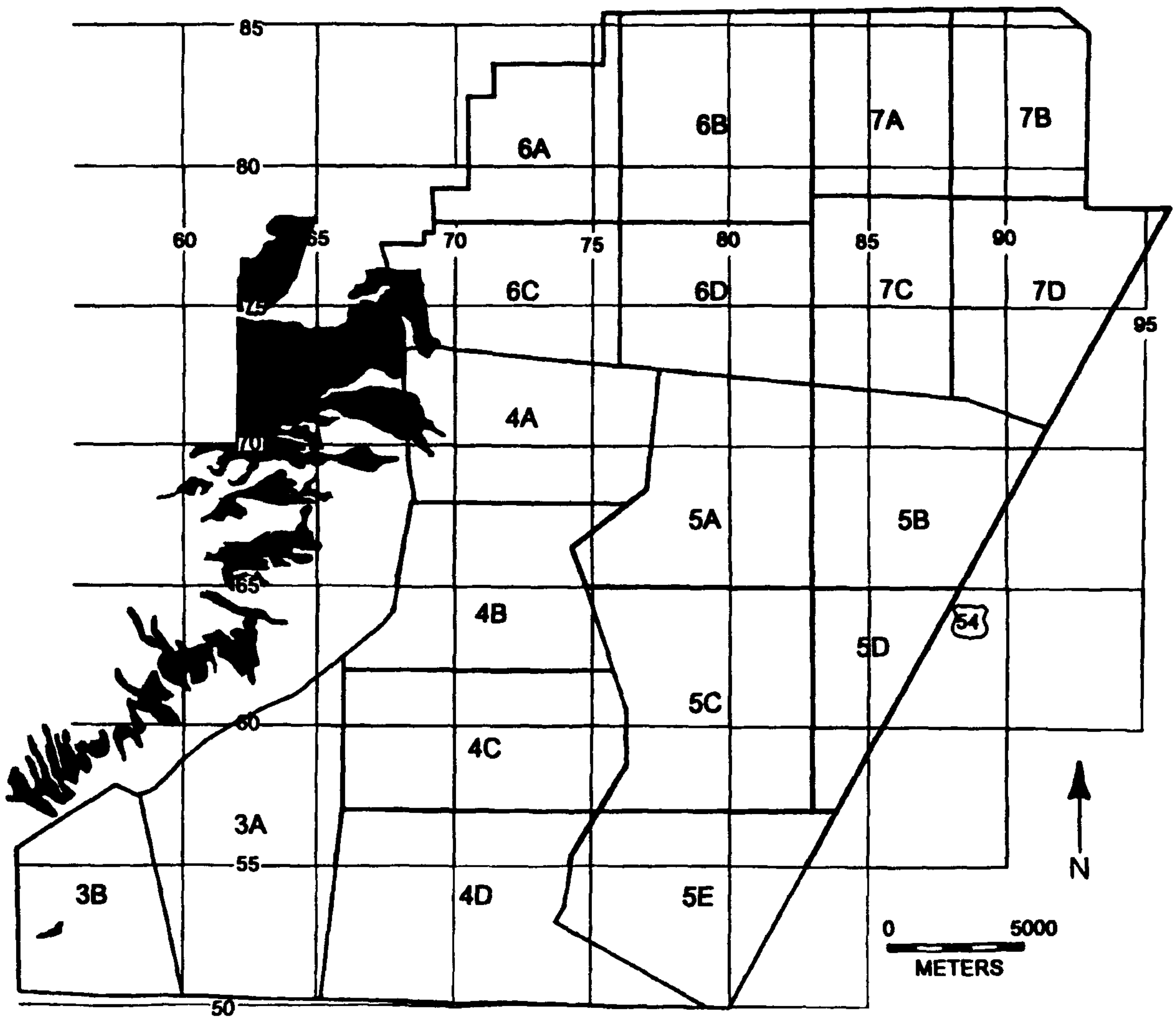
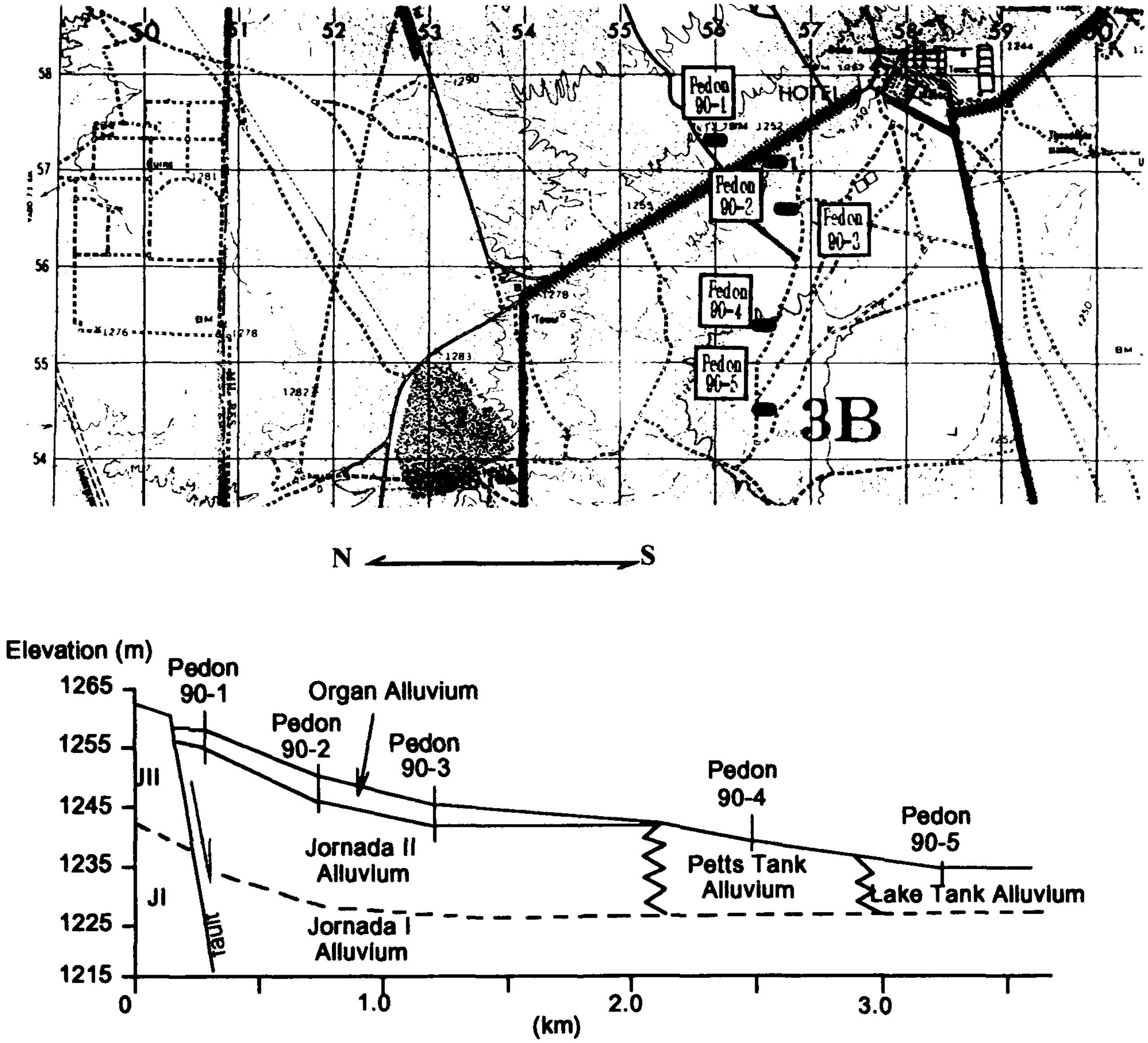


Figure III-9. Jornada II Surface Distribution (shaded areas) on Fort Bliss North (Jornada II did not occur to a mappable extent on Fort Bliss South.)



Deposit Ages (based on Gile et al. 1981)

Deposit	*Age (years B.P.)*
Lake Tank	Present to late Pleistocene
Organ	100 to 7000
Petts Tank	25,000 to 150,000
Jornada II	25,000 to 150,000
Jornada I	250,000 to 400,000

Figure III-10. Transect of backhoe trenches (black ovals on map) in the Doña Ana Range Camp area. Data for studied pedons are in Appendix A. This transect revealed that Organ and Jornada alluvium facies change from gravelly material in higher elevations to finer material basinward.

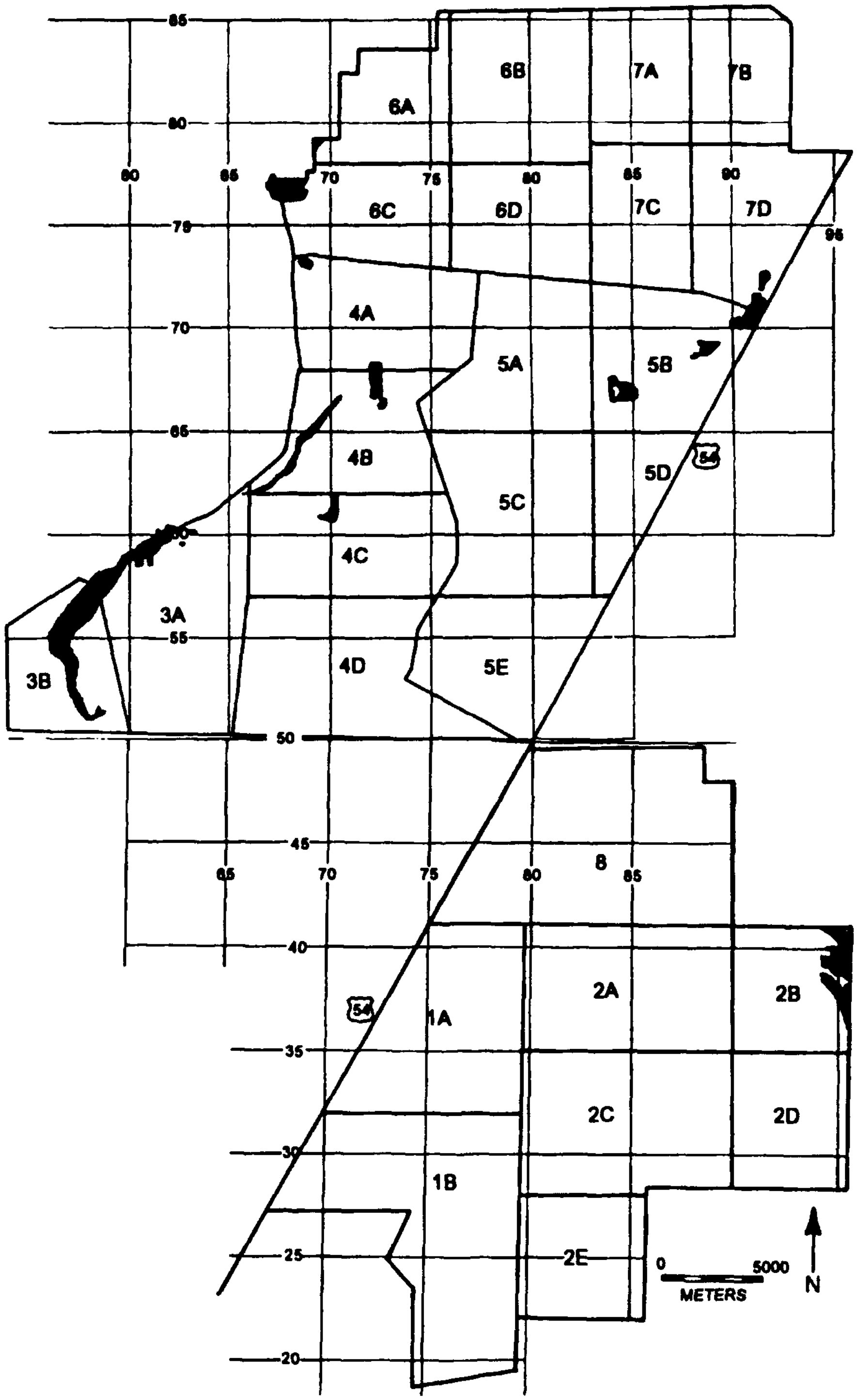


Figure III-11. Petts Tank Surface Distribution (shaded areas) on Fort Bliss North (top) and Fort Bliss South (bottom)

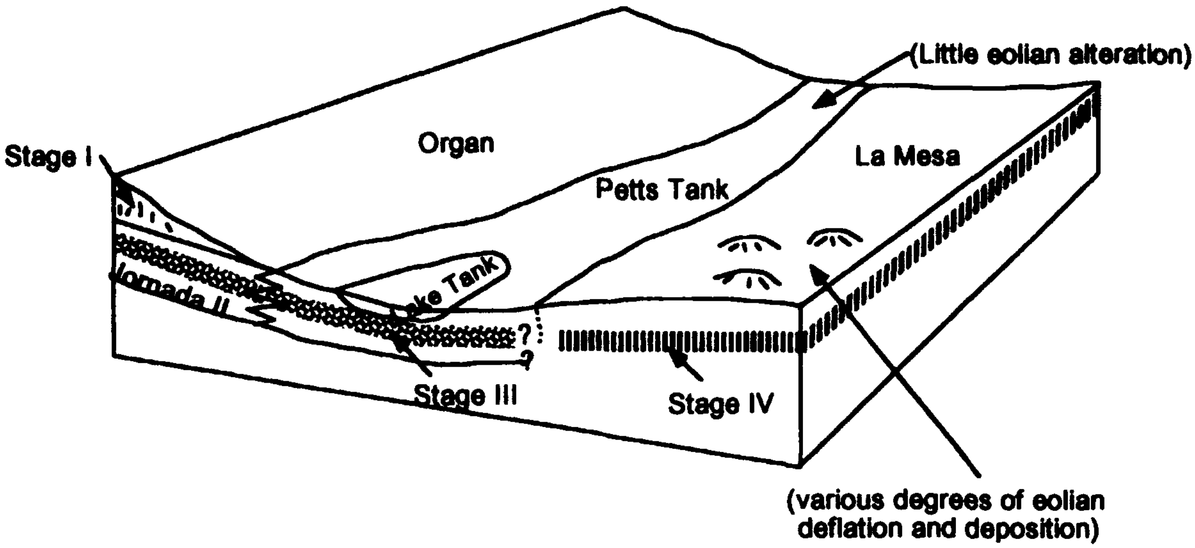


Figure III-12. Deposit Relationships in the Area South of Doña Ana Range Camp (vicinity of UTM 5755)

Fault Complex

The fault complex mapping unit is not a true geomorphic surface because it has formed during a broad time range and has several soil profiles associated with it. The fault complex, nevertheless, is included as a mapping unit because it is a distinctive landscape feature identifiable by its linear topographic configuration. The Fault Complex occupies relatively large areas in both Fort Bliss North and South (see Figure III-13). The fault complex mapping unit is composed of (1) fault scarps, which are the steep slopes formed by landscape displacement (Bates and Jackson 1987); (2) associated basins, which contain sediments resulting from both tectonic movement and eolian activity; and (3) downthrown blocks. Depending on the degree of erosion and sediment age, the fault complex can have a variety of associated soil types (see Figure III-14). East of the Organ and Franklin mountains are tectonic and neotectonic activity areas that contain numerous faults (Seager 1981; Seager et al. 1987; and Figure III-15). The fault complex mapping unit contains Petts Tank and Lake Tank mapping units where those units were too small to map separately on the 1:50,000-scale base map.

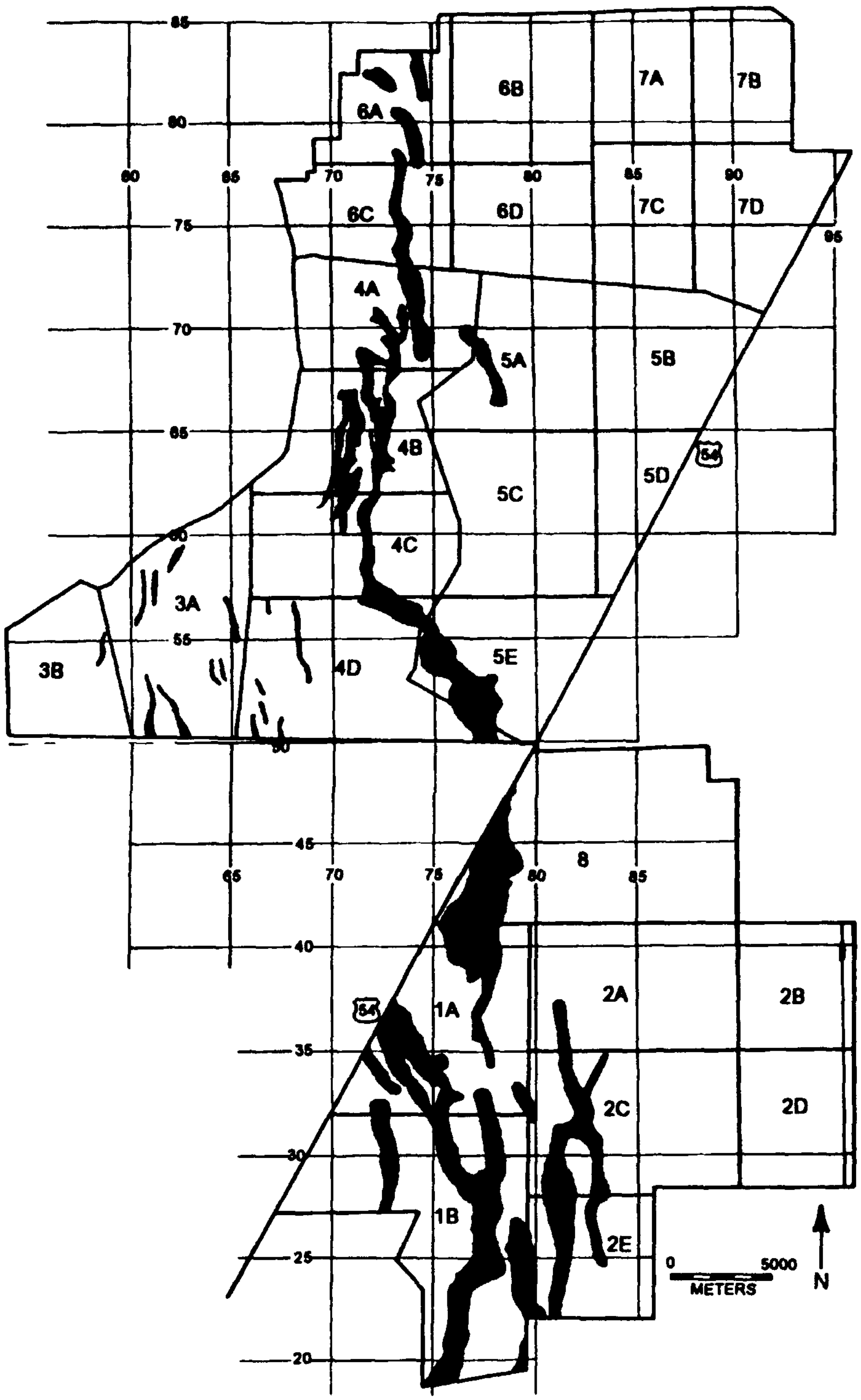


Figure III-13. Fault Complex Mapping Unit Distribution (shaded area) on Fort Bliss North (top) and Fort Bliss South (bottom)

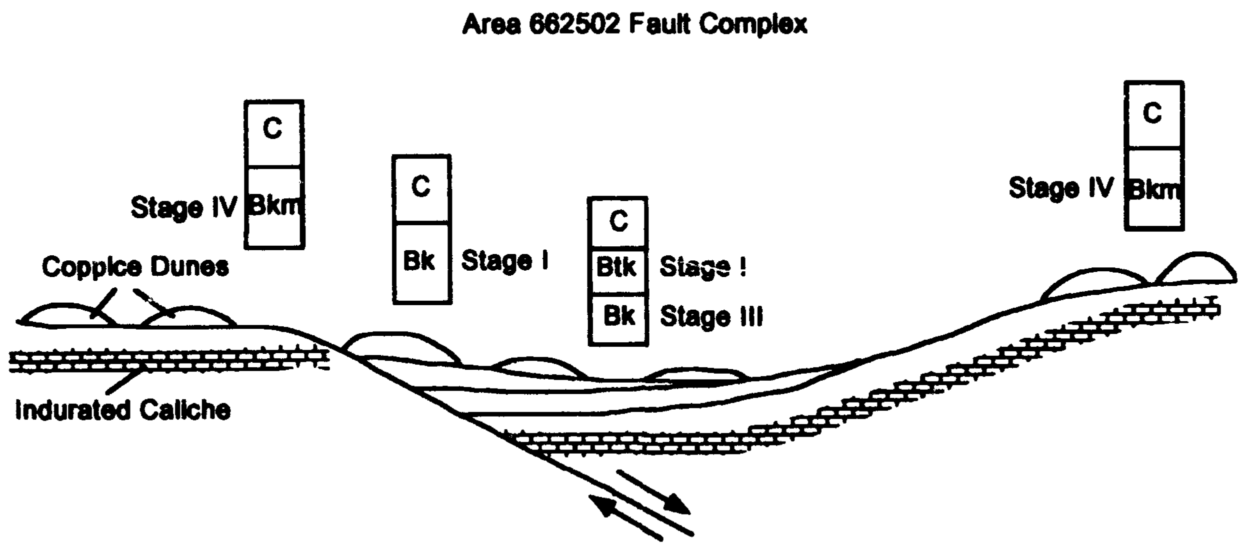


Figure III-14. Cross section of soils associated with the fault complex mapping unit. In many locations, the leeward western edge of the fault complex is buried by wind-blown sands, in contrast to the more-deflated windward eastern slopes.

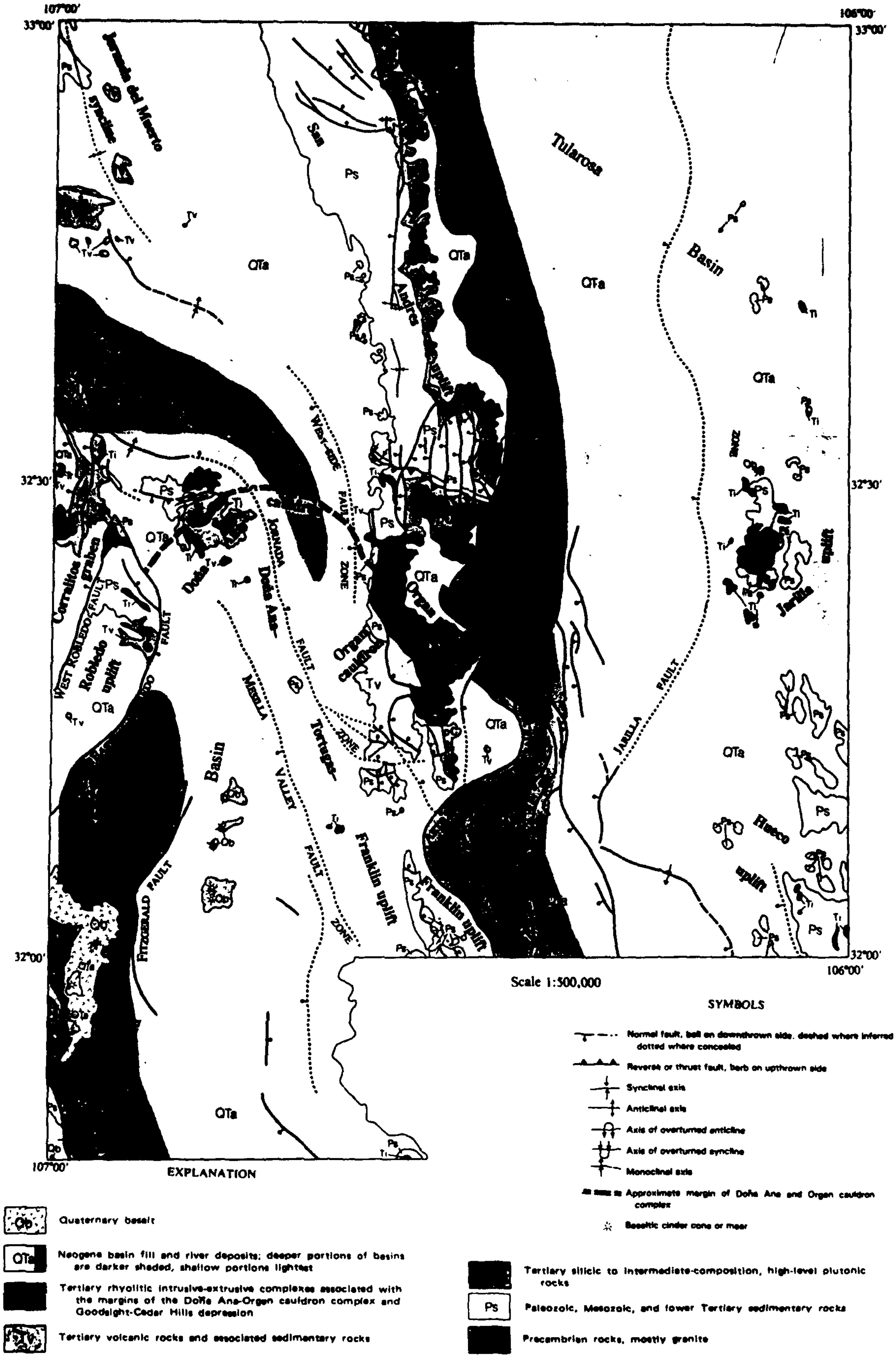


Figure III-15. Tectonic Map of Southern New Mexico (showing large number of faults in the Fort Bliss North Study Area; from Seager et al. 1987)

Isaacks' Ranch (fan deposits of earliest Holocene-latest Pleistocene age)

The Isaacks' Ranch surface appears to be 15,000 to 8,000 years old (Gile et al. 1981). It occurs on the Organ Mountains fan-piedmont (see Figure III-16) where it occupies a geomorphic position below Jornada II and above Organ (see Figure III-3). Isaacks' Ranch can be identified by its stage II carbonate morphology. If uneroded, it has a Bt argillic but the argillic is less pronounced and not as red as the Jornada II and Jornada I argillic horizons. Isaacks' Ranch alluvium slopes are less steep than older deposits (Seager 1981).

Fort Selden Complex (erosional surfaces and fans of late Pleistocene and Holocene age associated with the Camp Rice Fluvial Facies)

The Fort Selden Complex occurs in Fort Bliss North where Rio Grande downcutting (west of Fillmore Pass) and tectonic uplift has exposed the Camp Rice fluvial facies (see Figure III-17). The age of the Fort Selden unit in the Las Cruces area, where it contains components of Leasburg and Fillmore surfaces (Hawley 1965), is 15,000 to 100 B.P. (Gile et al. 1981). The Fort Selden mapping unit in the study area is characterized by soils with slight pedogenic development (Entisols) and the abundance of Rio Grande sands and mixed-rounded gravels. This unit primarily consists of erosional surfaces.

Lake Tank (basin floor deposits of late Pleistocene and Holocene age)

Lake Tank alluvium occurs in closed depressions on both Fort Bliss North and South (see Figure III-18). Lake Tank can be differentiated from Petts Tank because it has experienced less soil development. In most cases, Lake Tank has only stage I carbonate filaments. In the closed depression south of Old Coe Lake, however, Lake Tank deposits contain powdery stage II nodules that produced radiocarbon dates of 8220 ±120 B.P. (see Chapter VIII). The Lake Tank alluvium appears to be older than Holocene in some locations, such as the Davis Tank area just north of the Fort Bliss-White Sands boundary, which contains tusks, teeth, and bones of Pleistocene megafauna. In most cases, Lake Tank occurs in depressions that appear to have resulted from faulting. Some isolated depressions, however, lack the linearity typical of fault-produced depressions and may have an eolian origin. Vertisols occur in the Lake Tank alluvium in the Old Coe Lake and Stewart Lake depressions.

Organ (eolian and alluvial deposits of Holocene age)

The Organ geomorphic surface associated with fan-piedmont sediments occurs mainly in Fort Bliss North with minor amounts in Fort Bliss South (see Figure III-19). Organ alluvium, which is well dated with radiocarbon, ranges in age from 7,000 to 100 B.P. (Gile et al. 1981). The Organ alluvium can be identified by its braided-channel pattern and lowest geomorphic position, which is graded very close to the modern arroyo system (Seager 1981) (see Figure III-3). The Organ alluvium contains soil profiles less-developed soil profiles than do older alluvium. Organ generally has stage I filaments and may contain reddish-brown argillic or cambic horizons (Gile et al. 1981).

Much of the La Mesa basin floor is buried with eolian sediments of Organ age. These eolian deposits vary in thickness from less than a meter to a few meters. Unlike the fan-piedmont Organ sediments,

Organ-age eolian sediments are not readily mappable because (1) there is no land surface expression of the subsurface material and (2) the occurrence and thickness of these deposits within a small area varies extensively.

The Organ alluvium has paleoclimatic significance because its deposition appears to represent an early Holocene shift toward aridity. Organ alluvium has been subdivided into three members–Organ I, II, and III–(Gile et al. 1981). Future studies of the three members may help refine our understanding of paleoclimatic conditions during the Holocene in the Fort Bliss area.

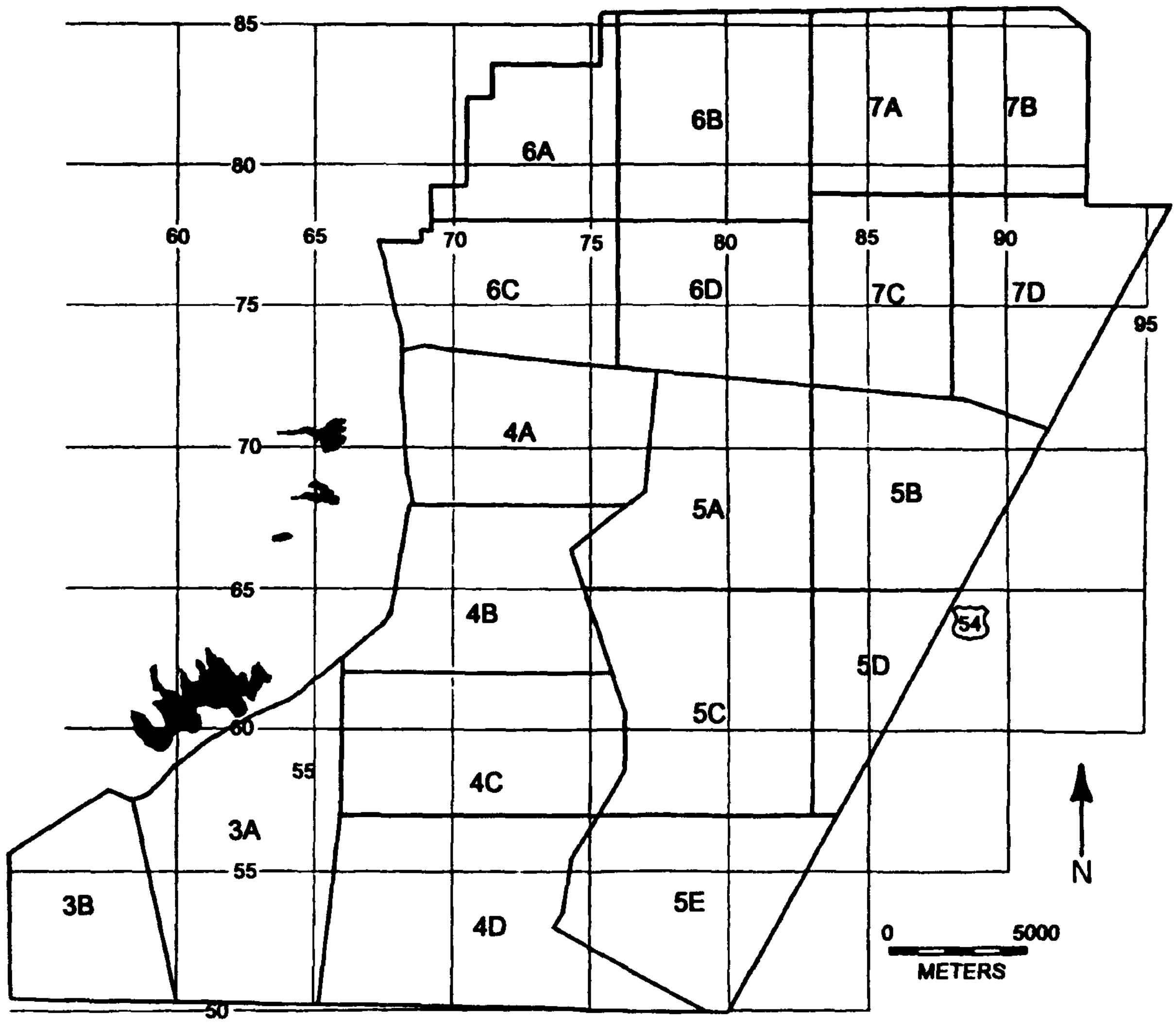


Figure III-16. Isaacks' Ranch Geomorphic Surface Distribution (shaded areas) on Fort Bliss North (No Isaacks' Ranch was mapped on Fort Bliss South.)

Historic Eolian and Arroyo Deposits

Historic eolian and arroyo deposits are widespread across the Fort Bliss study area. Deflation and eolian sedimentation are active processes that currently are modifying the Fort Bliss landscape. Army artifacts buried beneath a couple of meters of eolian sediments testify to the rapid rate of deposition. Eolian deposition is most active in the spring when soil moisture is low and wind velocities are high (Blair et al. 1990).

Arroyo systems continue to drain and deposit sediments in relief areas, such as the mountainous regions and along faulted terrain. Arroyos are most active during the summer thunderstorm season.

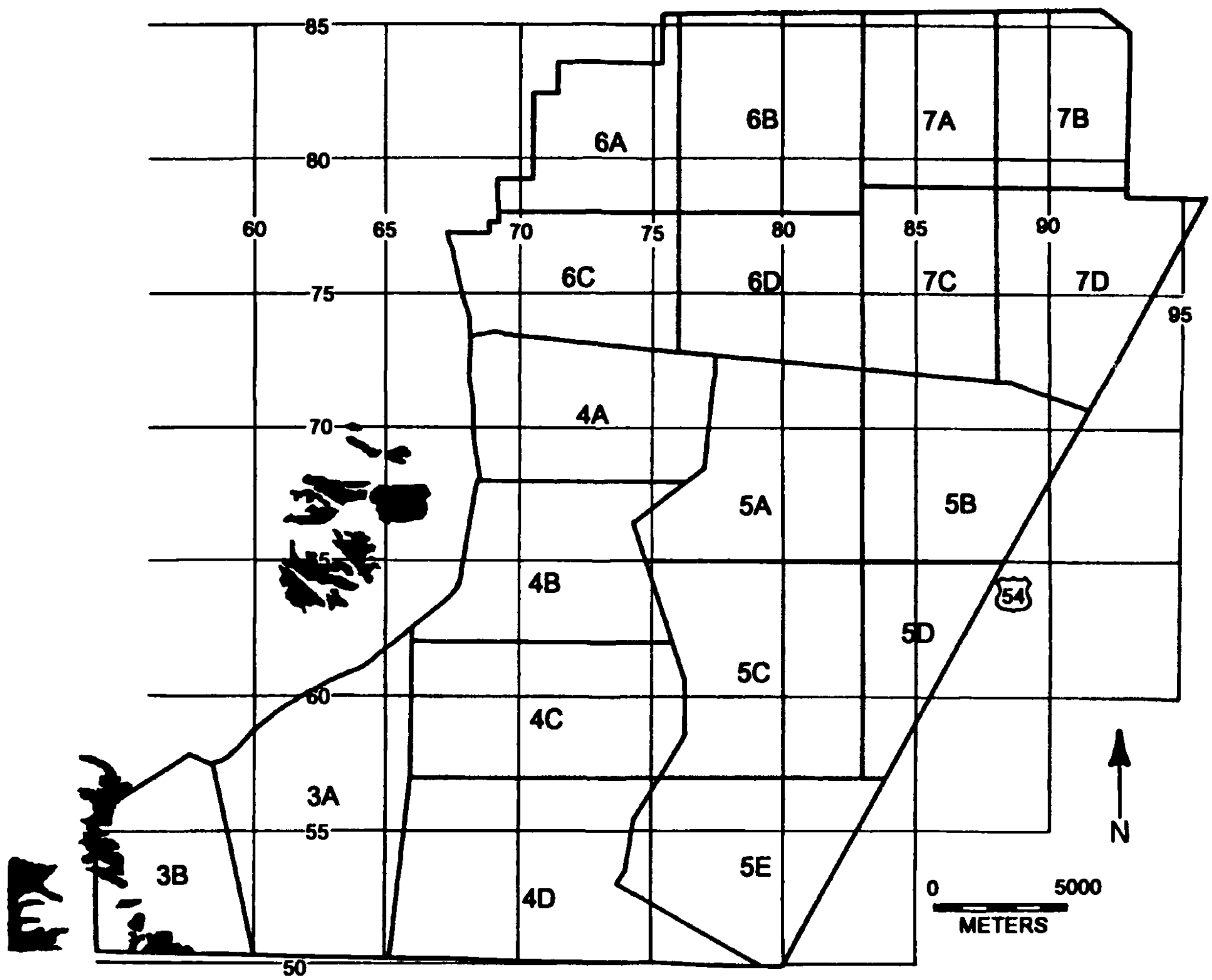


Figure III-17. Fort Selden Complex Mapping Unit Distribution (shaded areas), limited to Fort Bliss North

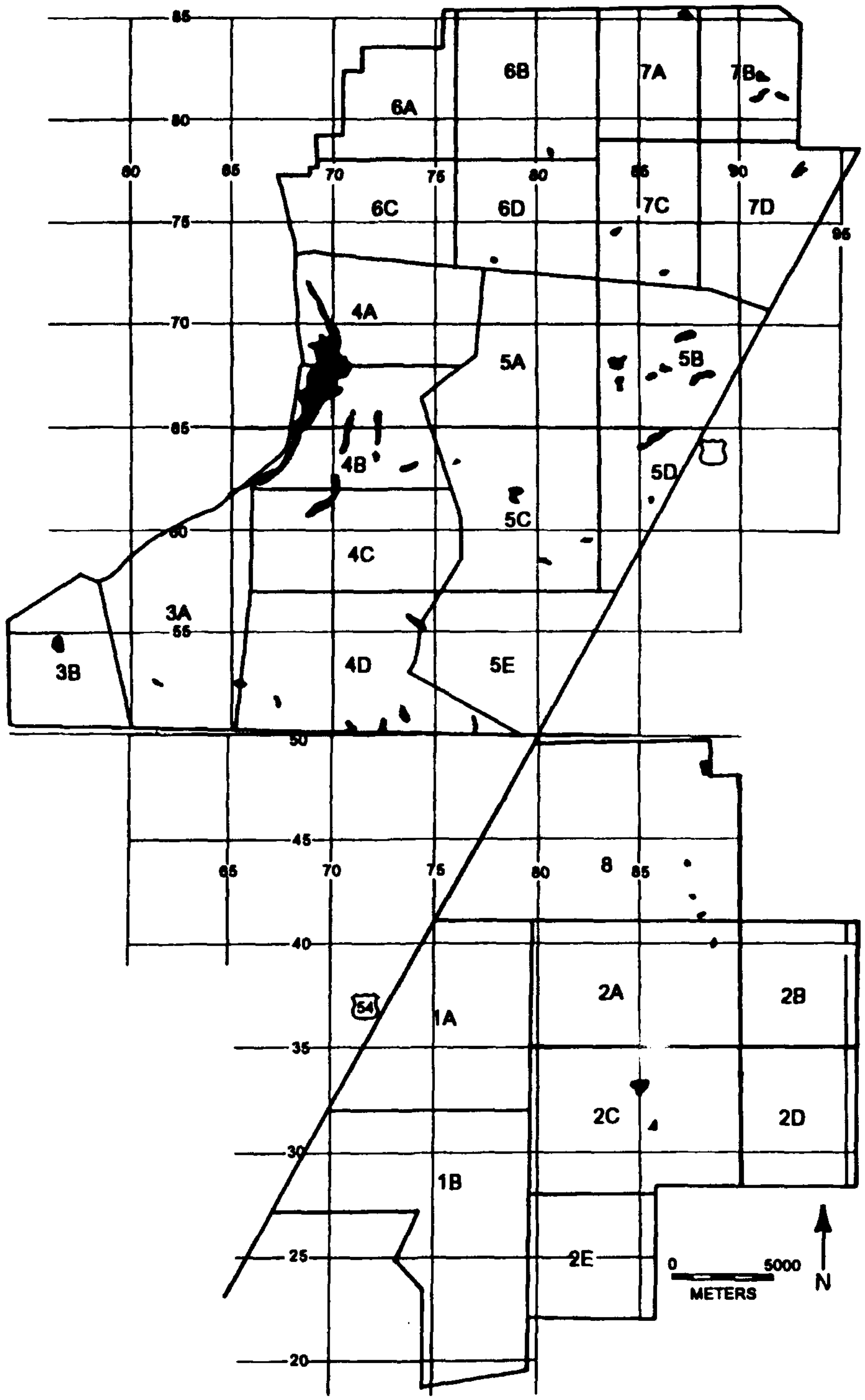


Figure III-18. Lake Tank Geomorphic Surface Distribution (shaded areas) on Fort Bliss North (top) and Fort Bliss South (bottom)

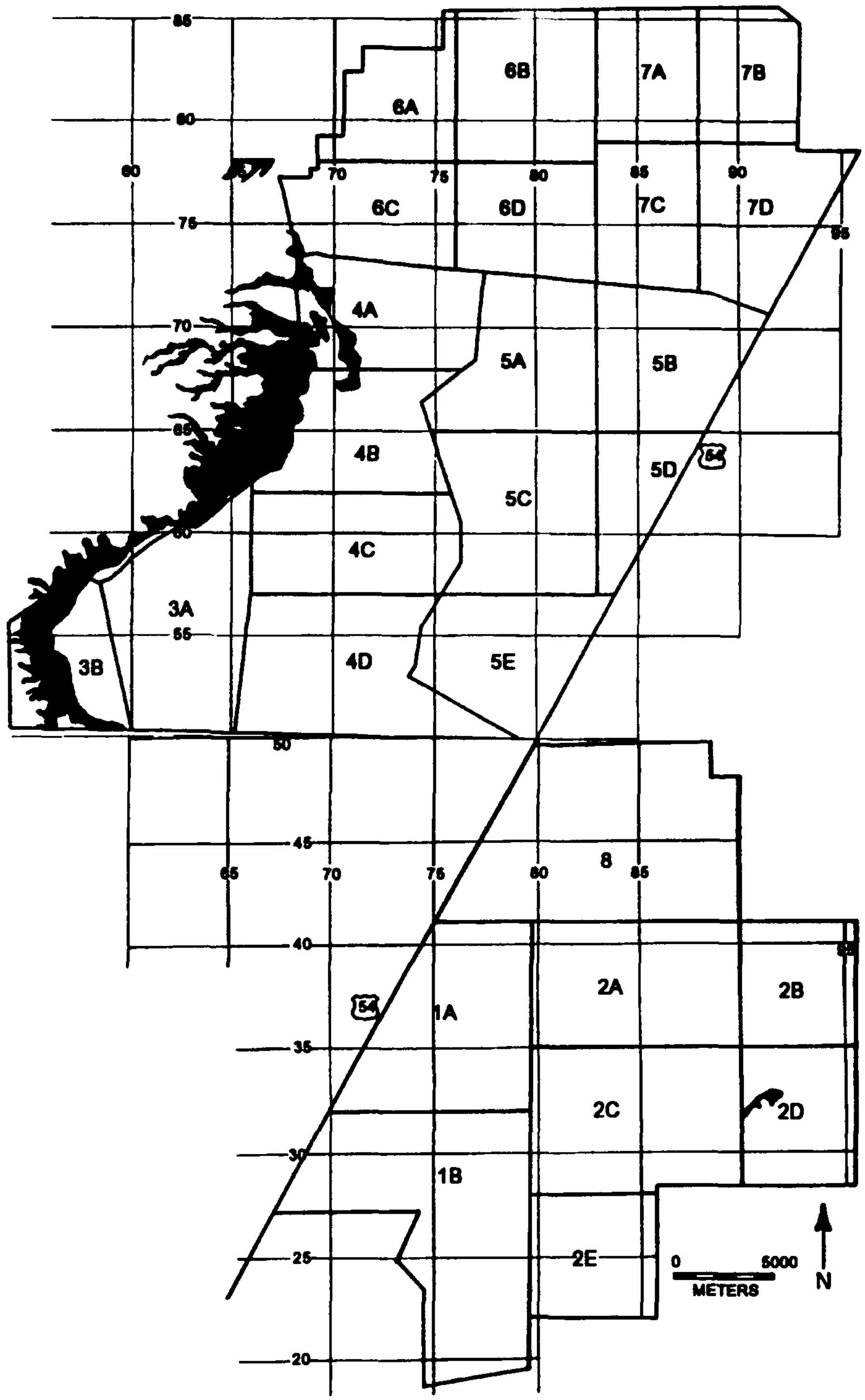


Figure III-19. Organ Fan-Piedmont Alluvium Distribution on Fort Bliss North (top) and Fort Bliss South (bottom)

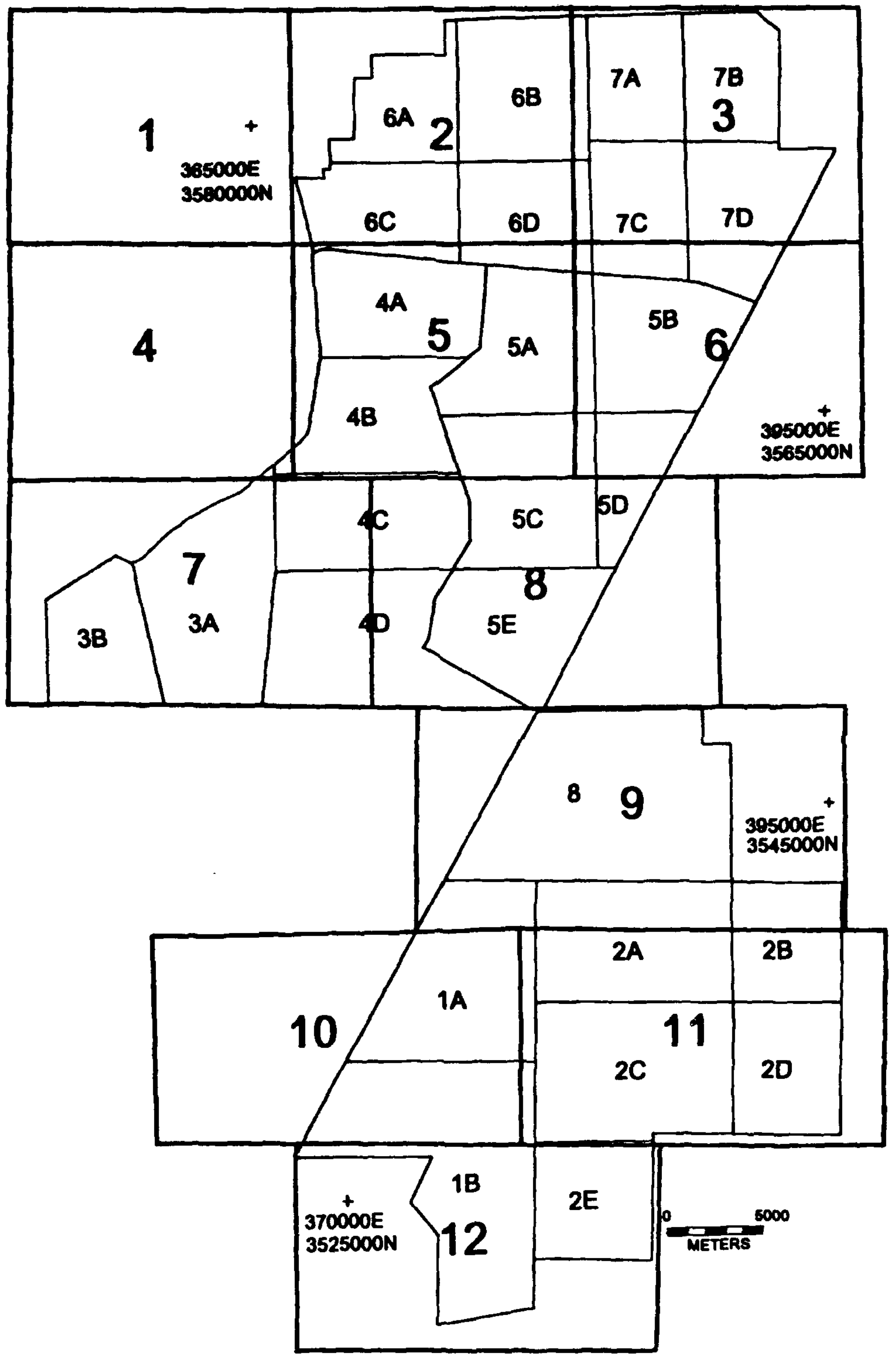


Figure III-20. Index Map of Geomorphic Surfaces

Map Legend:

Symbol	Mapping Unit (see preceding text in this chapter for mapping unit descriptions)
LM	La Mesa Geomorphic Surface
JI	Jornada I Geomorphic Surface
JII	Jornada II Geomorphic Surface
PT	Petts Tank Geomorphic Surface
FC	Fault Complex Mapping Unit
IR	Isaacks' Ranch Geomorphic Surface
FS	Fort Selden Complex Mapping Unit
LT	Lake Tank Geomorphic Surface
OR	Organ Geomorphic Surface
BR	Bedrock

Areas that have an intricate association of two mapping units are signified by combining the symbols, such as OR/IR. The first symbol indicates the dominant mapping unit.

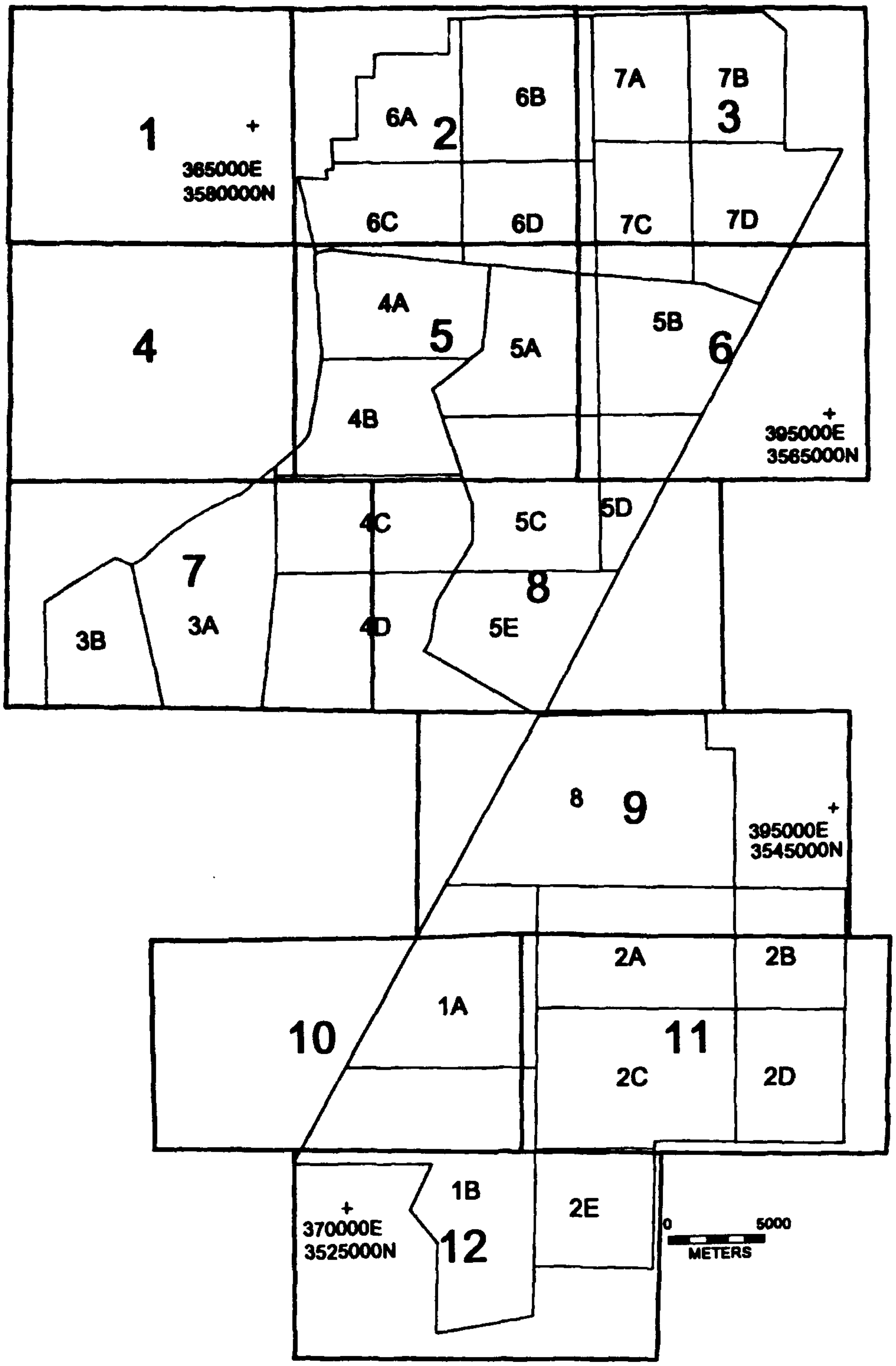
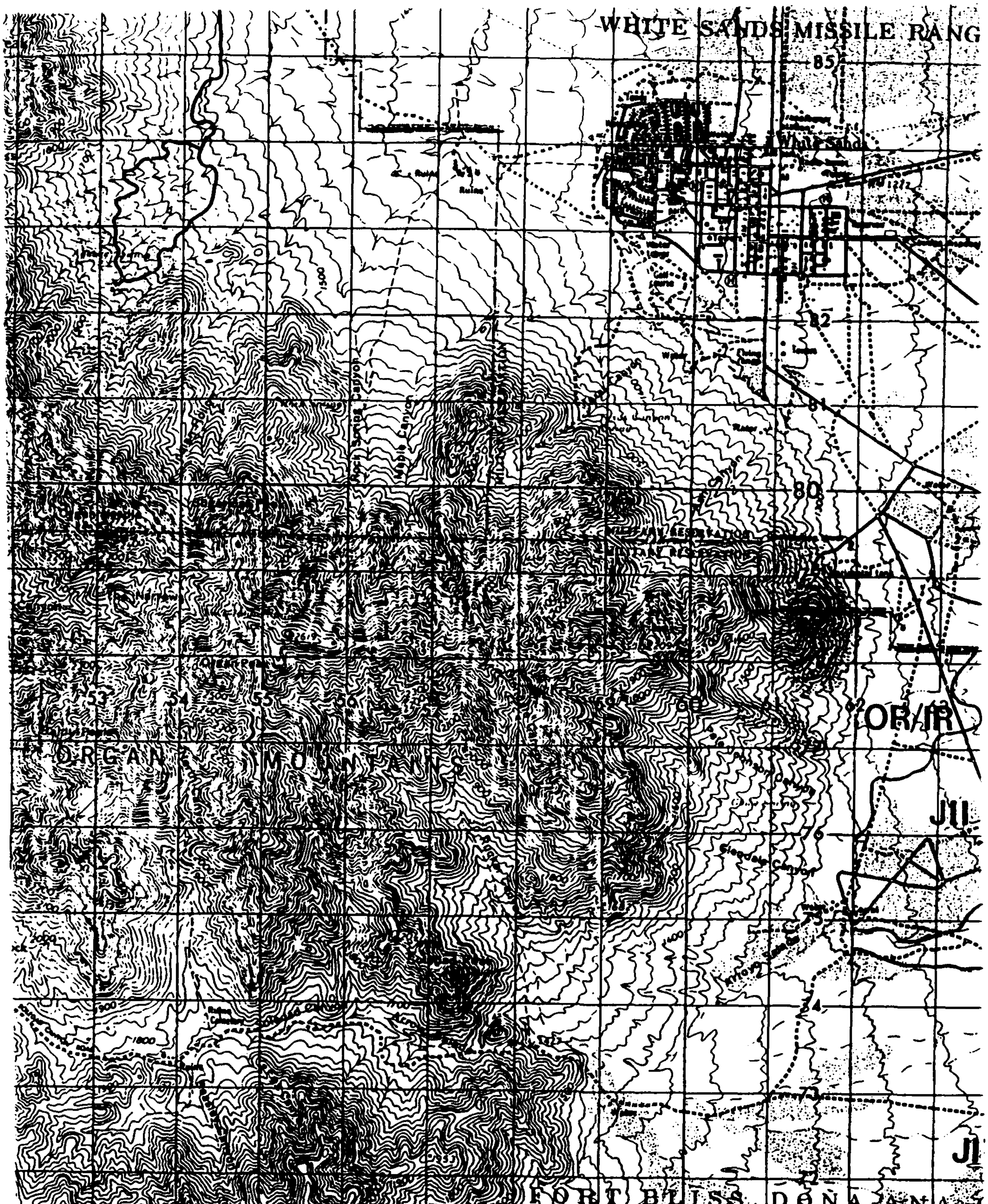


Figure III-20. Index Map of Geomorphic Surfaces

Map Legend:

Symbol	Mapping Unit (see preceding text in this chapter for mapping unit descriptions)
LM	La Mesa Geomorphic Surface
JI	Jornada I Geomorphic Surface
JII	Jornada II Geomorphic Surface
PT	Petts Tank Geomorphic Surface
FC	Fault Complex Mapping Unit
IR	Isaacks' Ranch Geomorphic Surface
FS	Fort Selden Complex Mapping Unit
LT	Lake Tank Geomorphic Surface
OR	Organ Geomorphic Surface
BR	Bedrock

Areas that have an intricate association of two mapping units are signified by combining the symbols, such as OR/IR. The first symbol indicates the dominant mapping unit.



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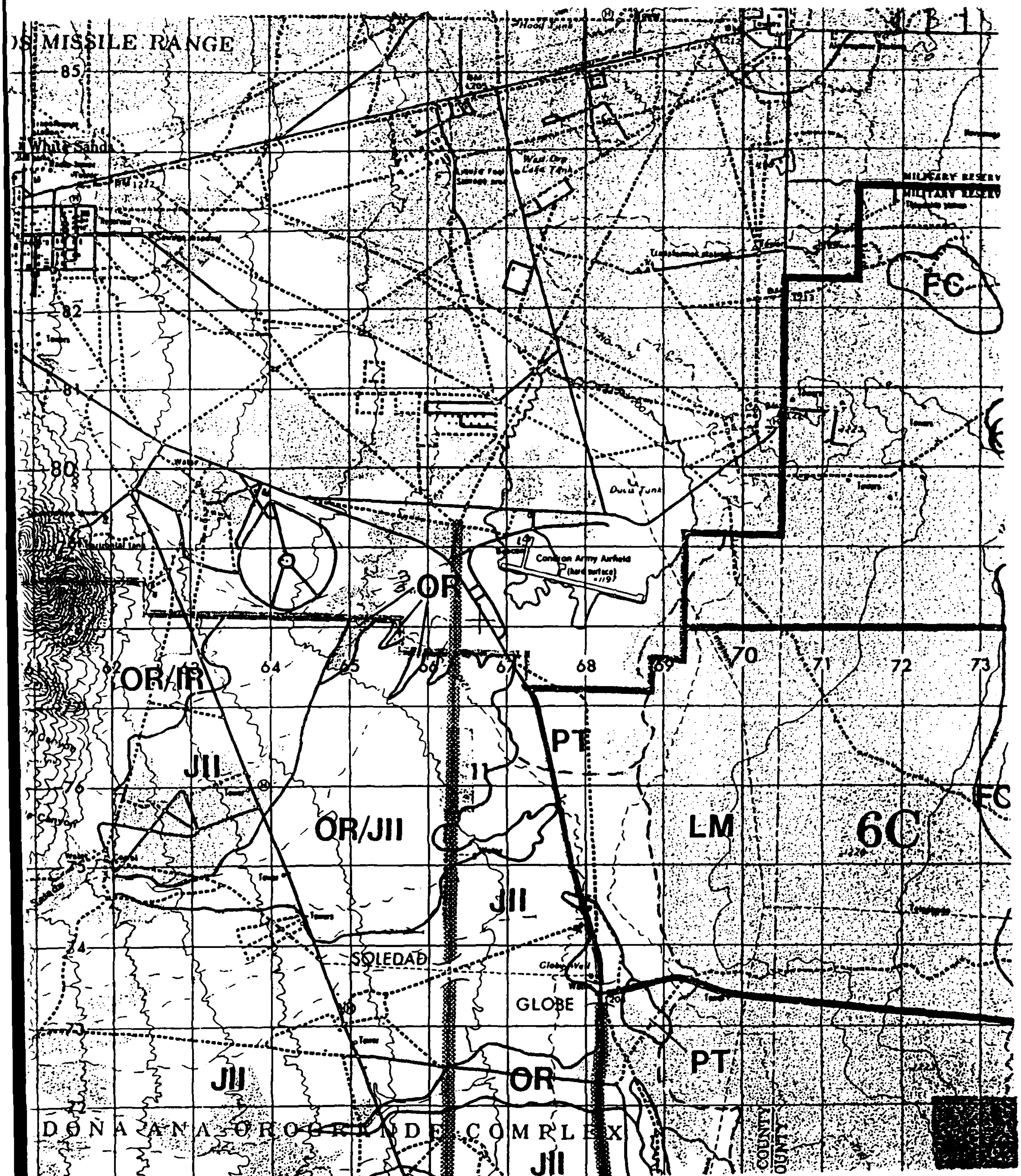
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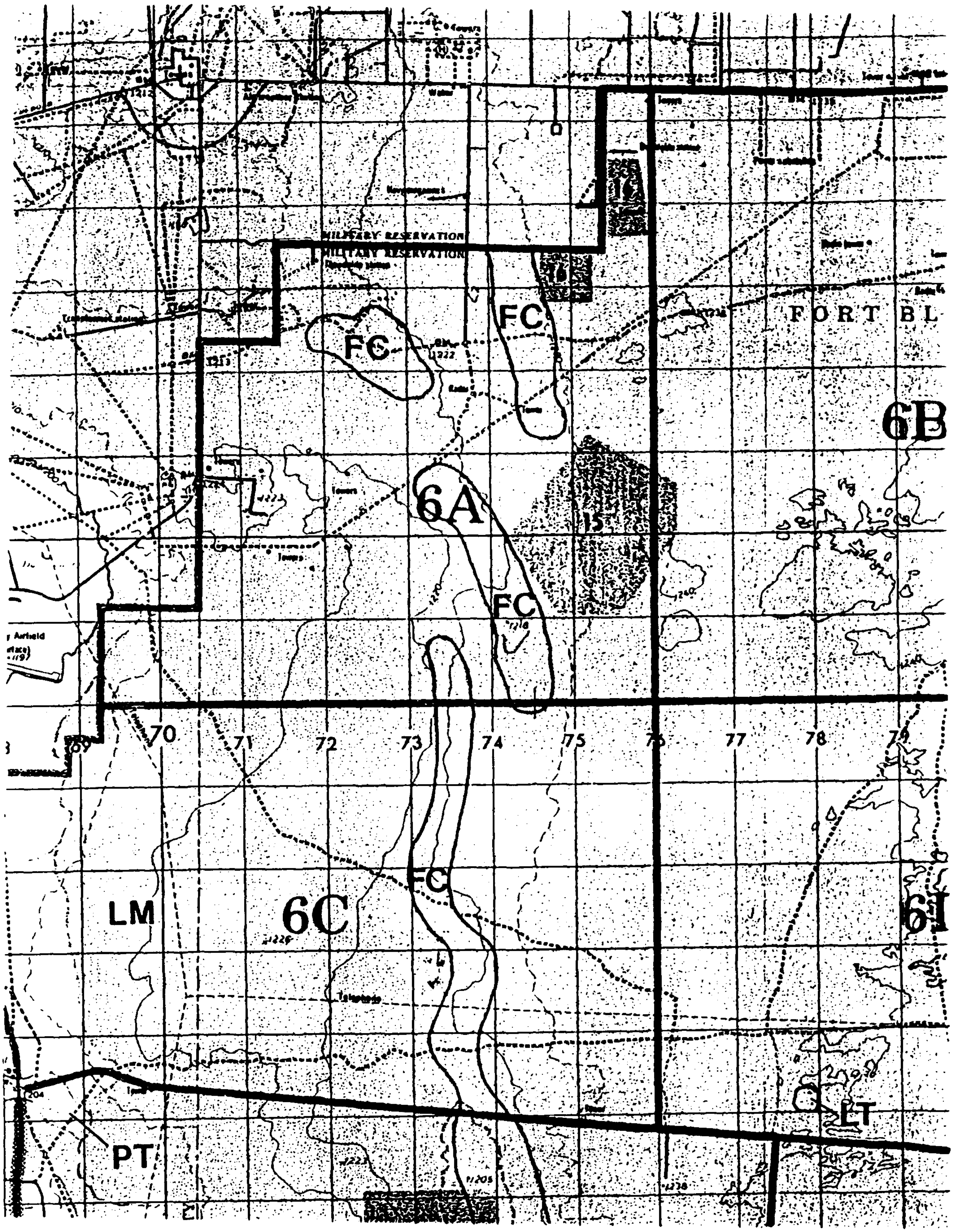

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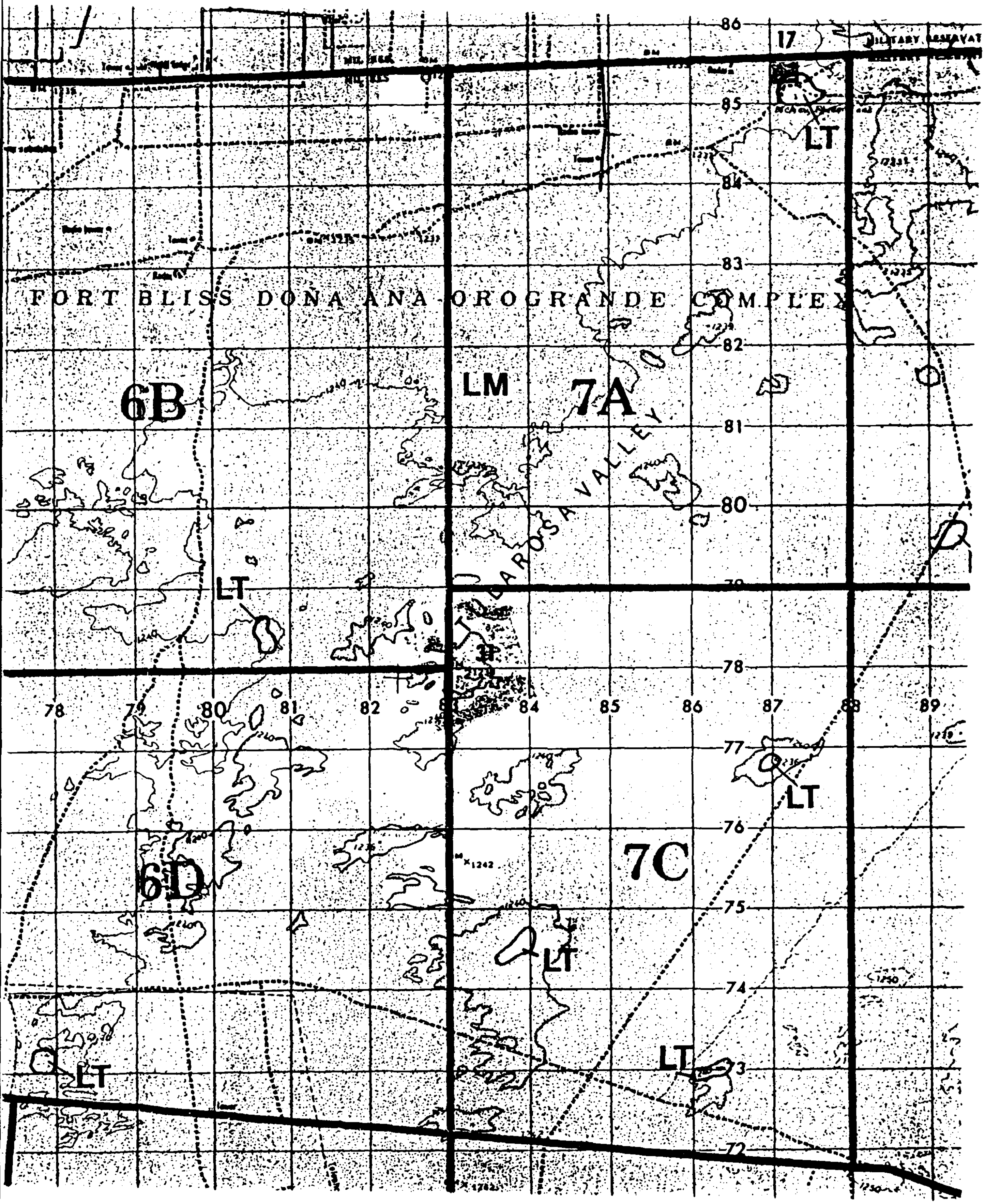
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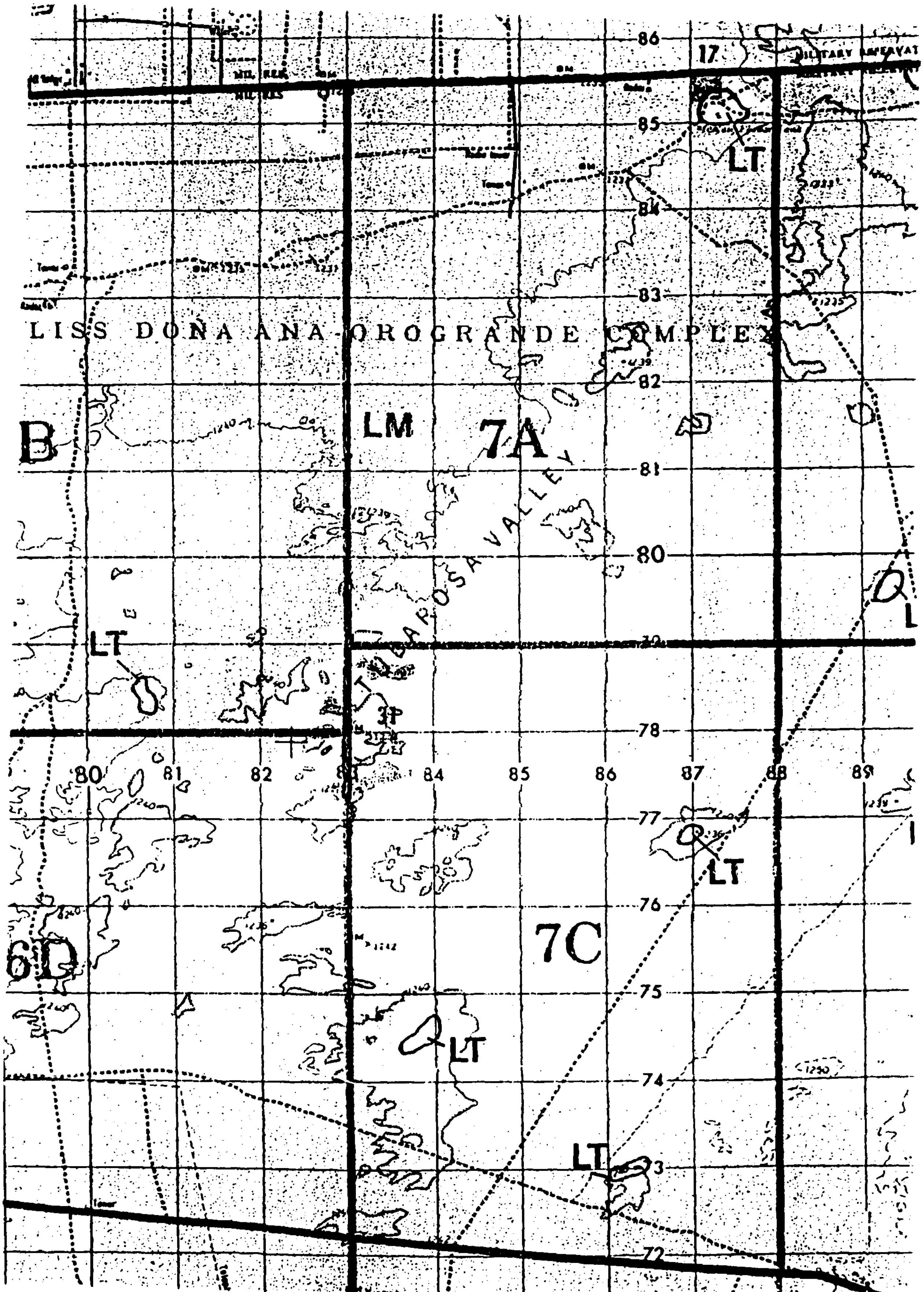

LISS DOÑA ANA-OROGRANDE COMPLEX
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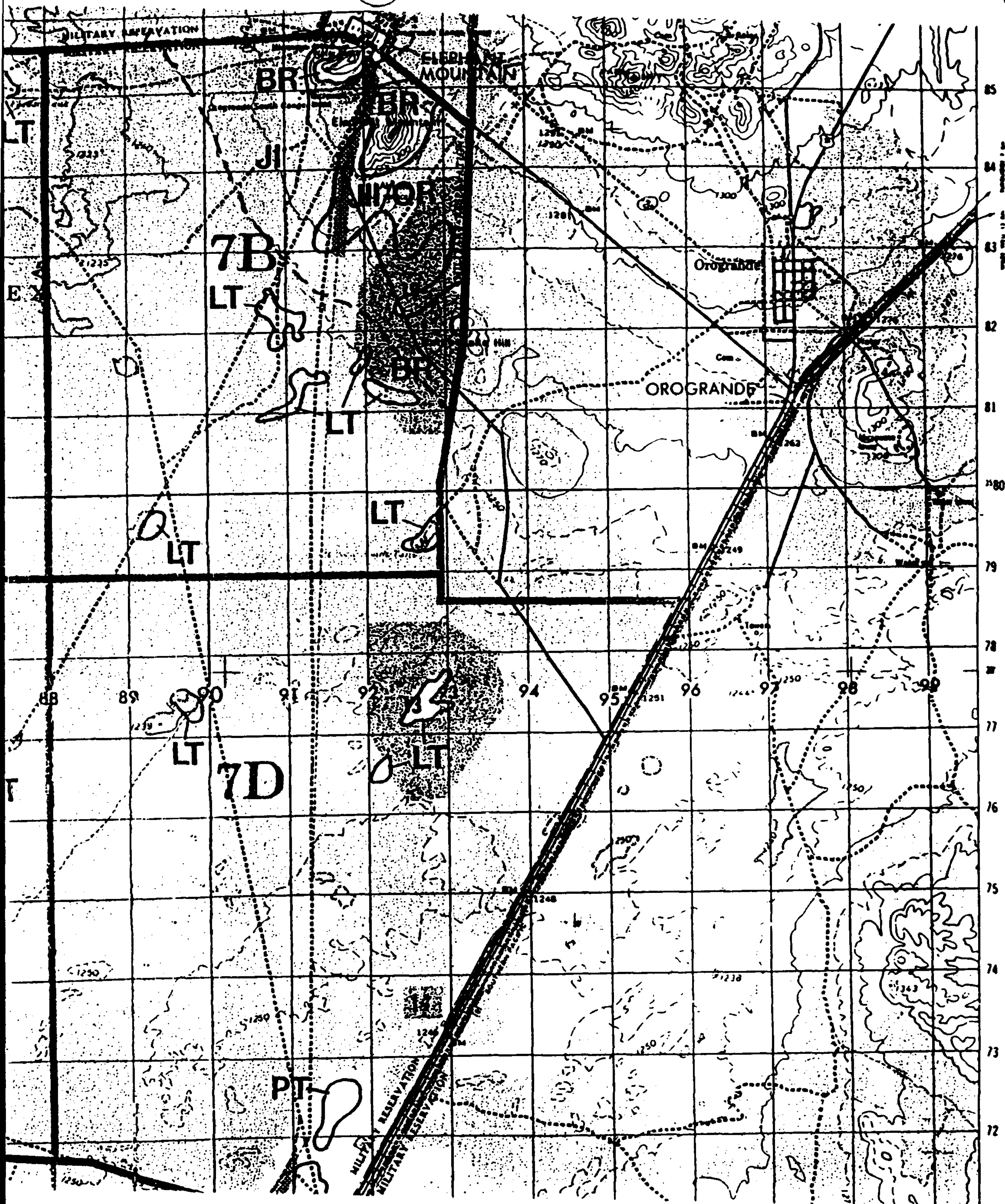
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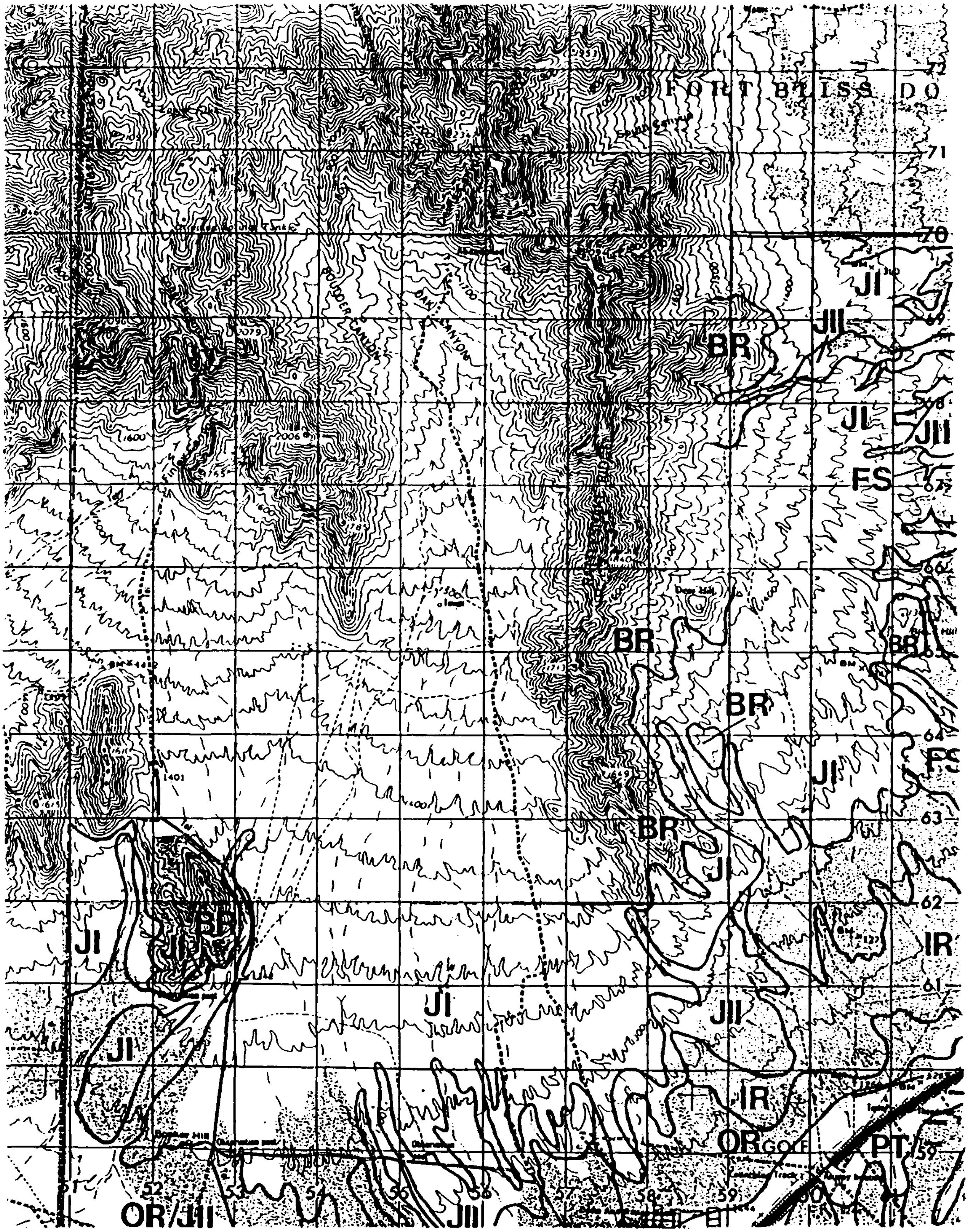
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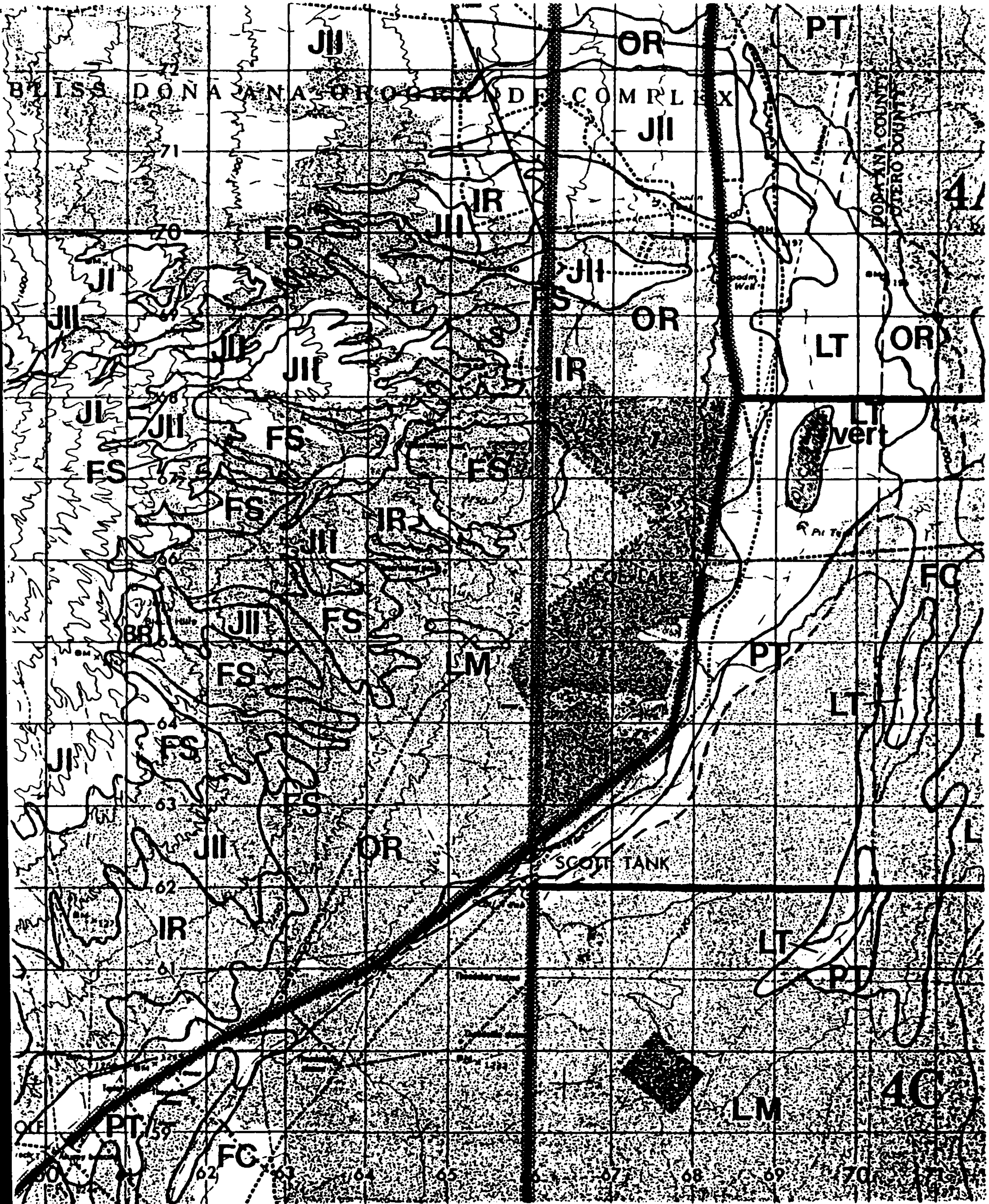
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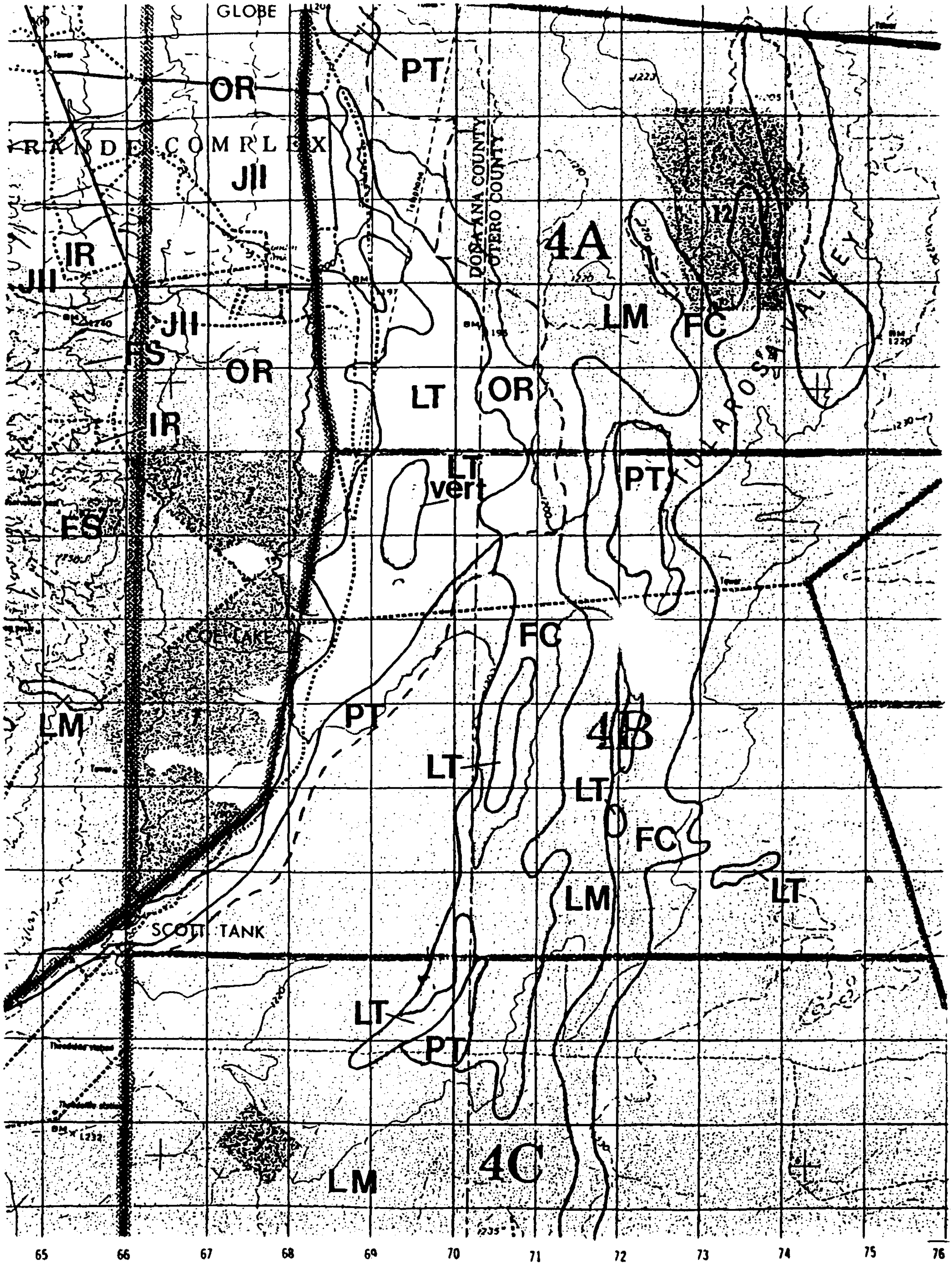
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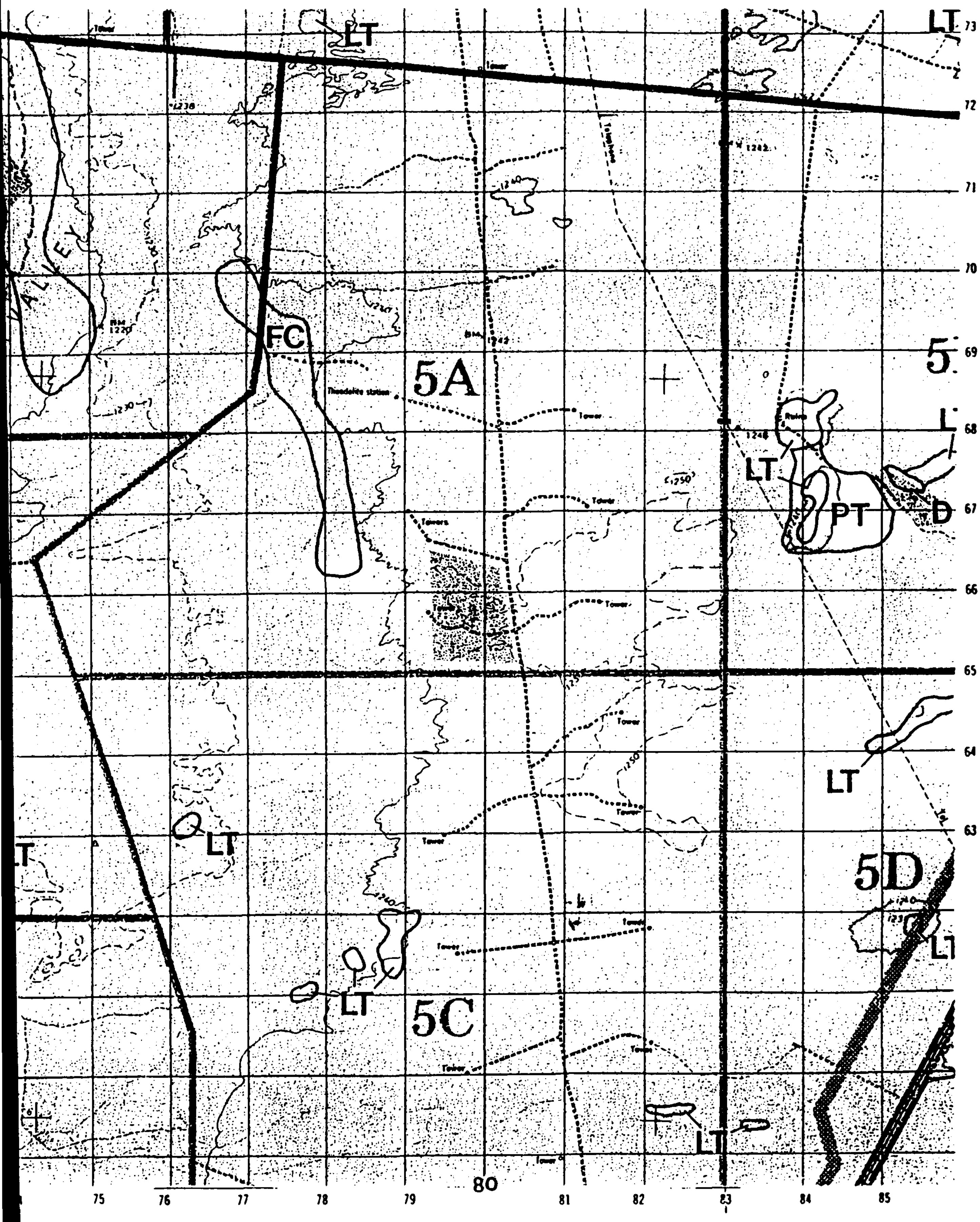
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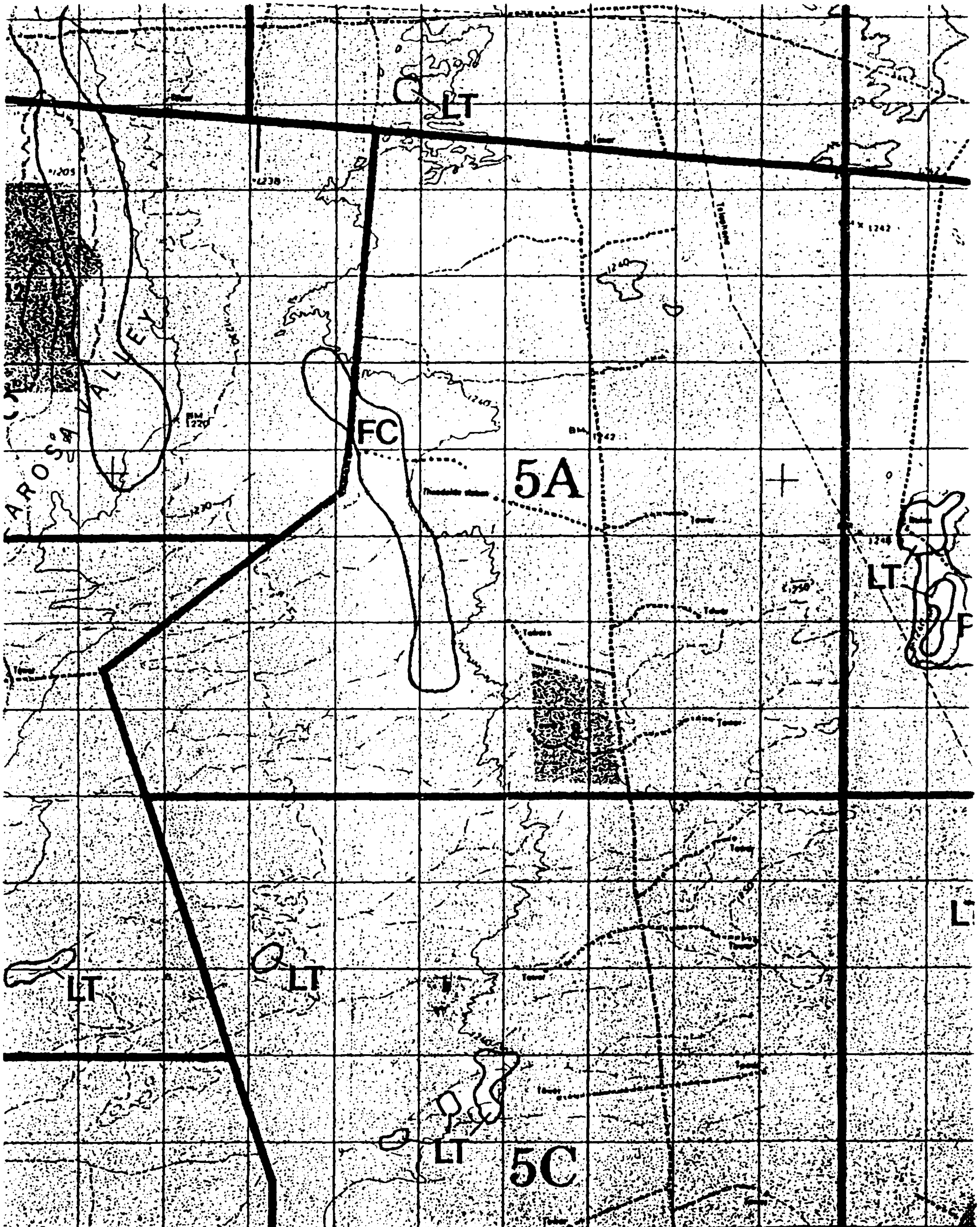
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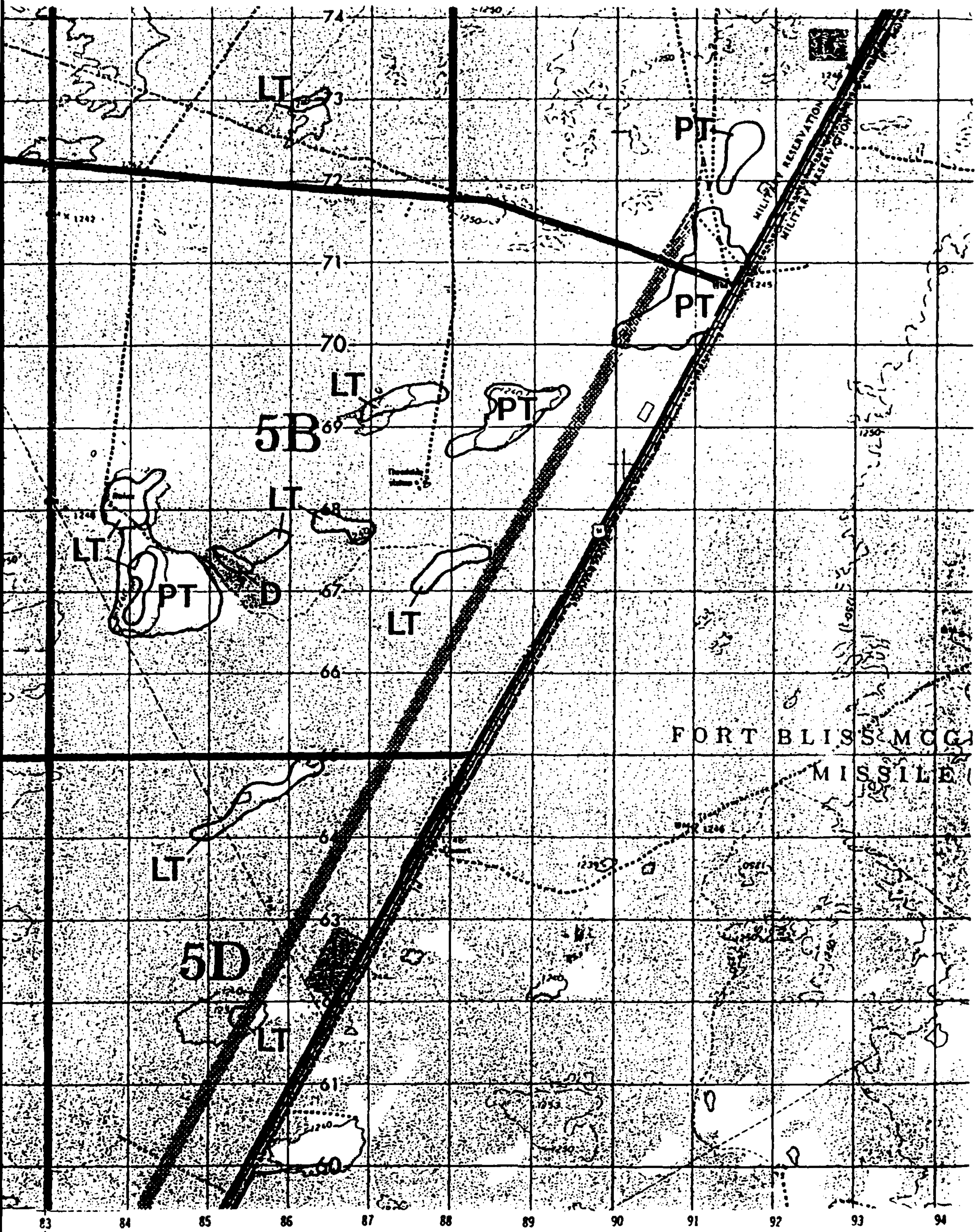
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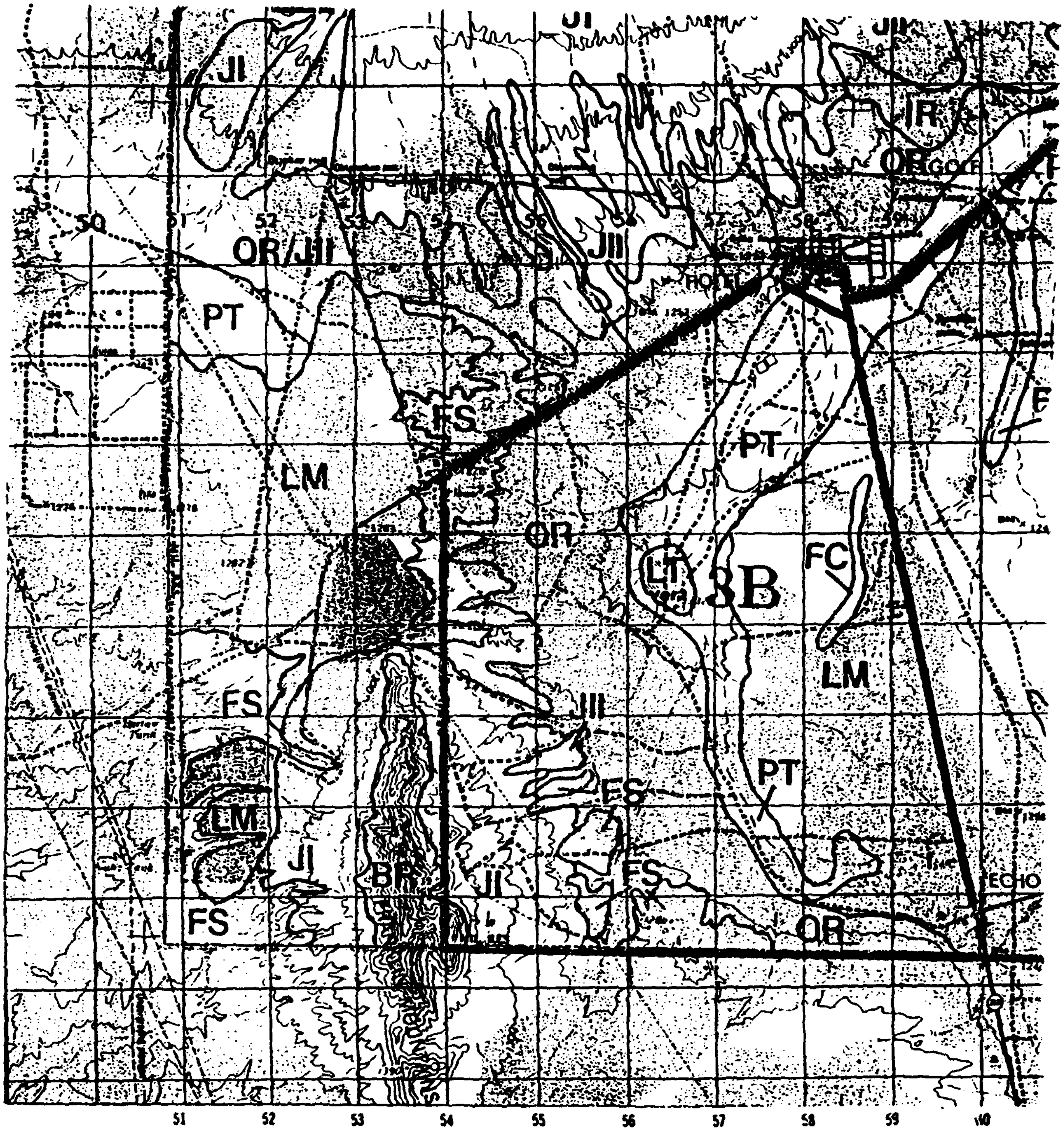

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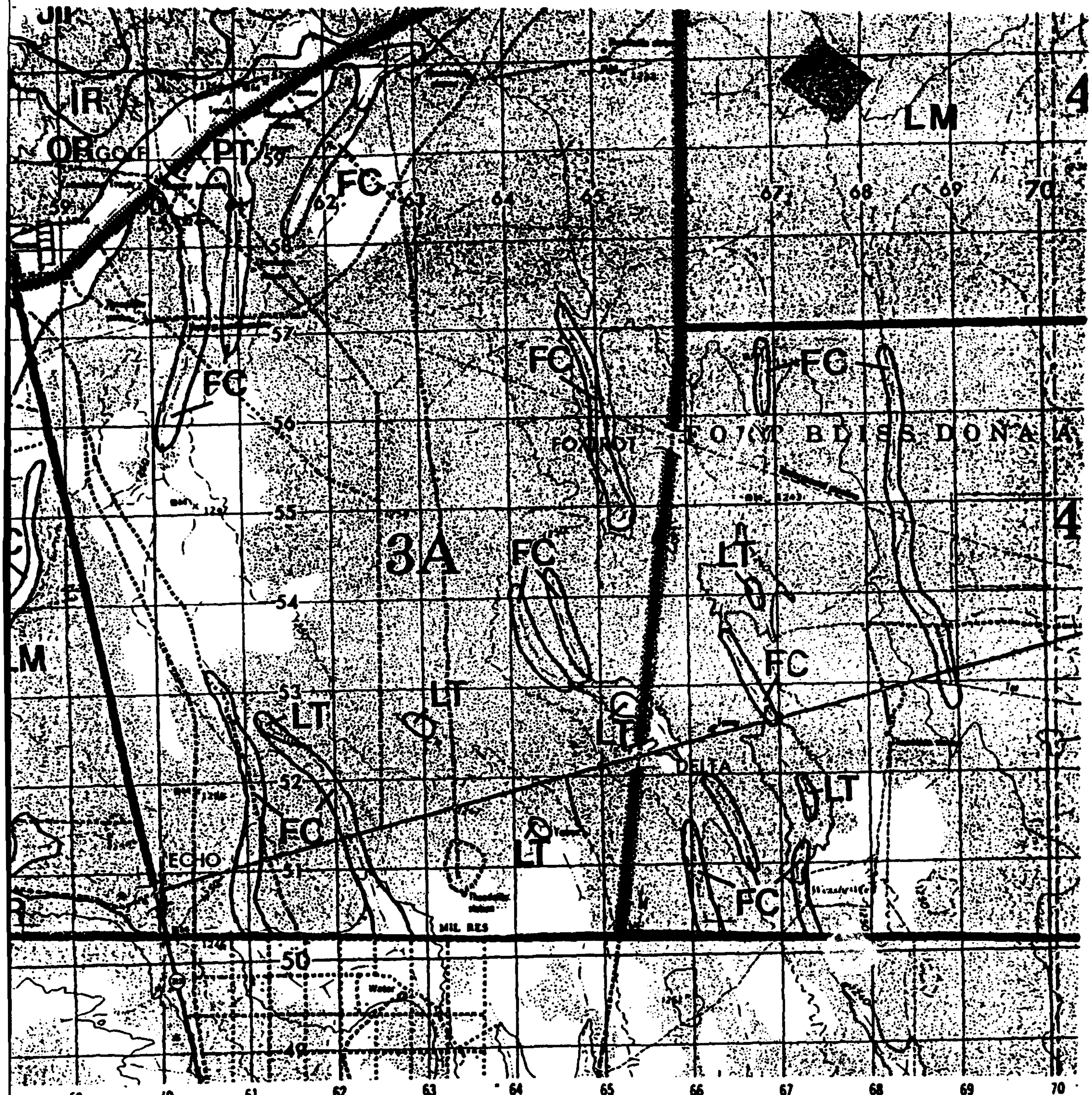
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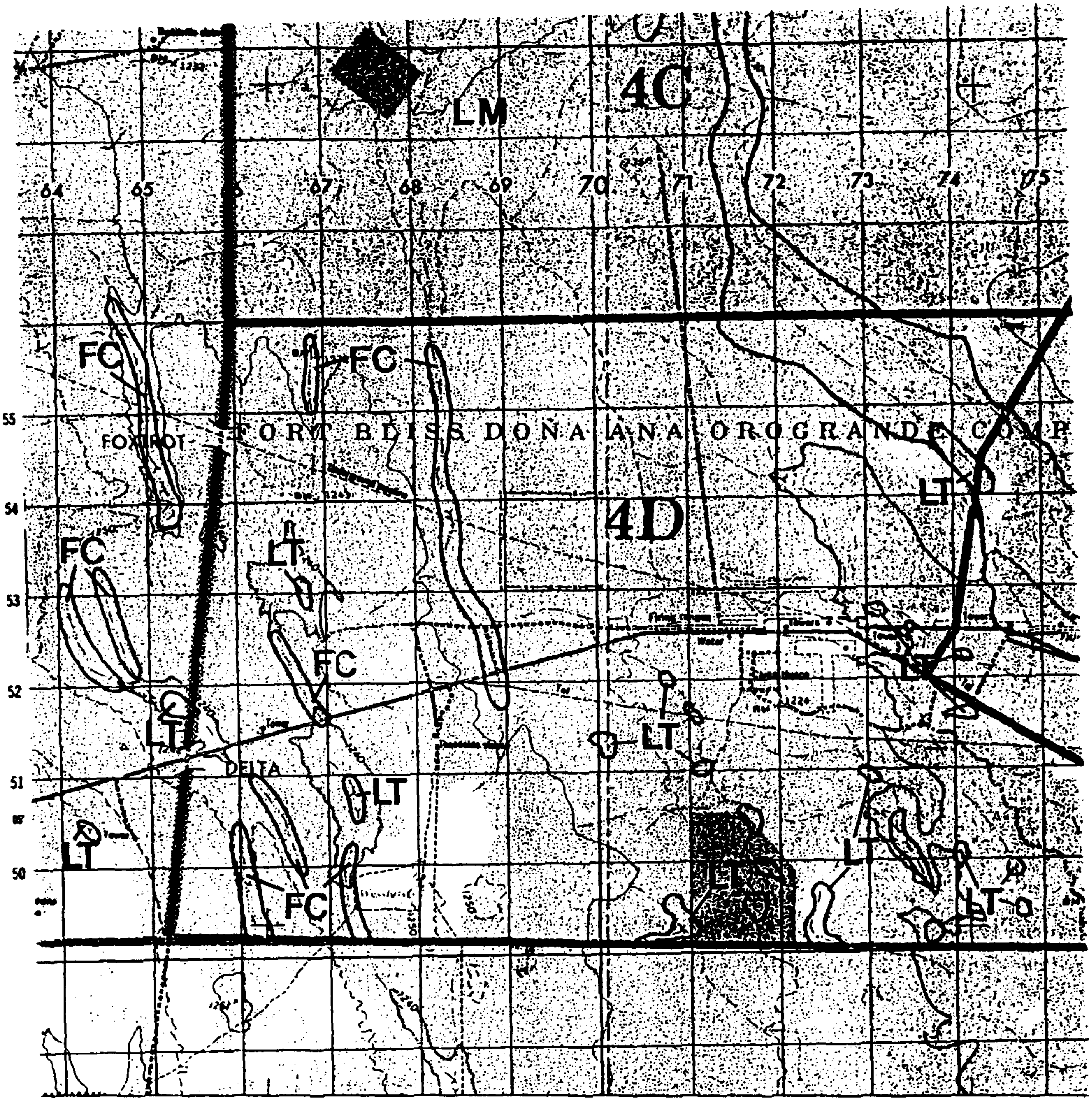
LM
FC
LT
LT
LT
FC
DELTA
LT
FC
ECHO
LT
FC
MIL RES
50
59
60
61
62
63
64
65
66
67
68
69
70

1


4C
LM
4D
FORT BLISS DONA ANA OROGRANDE COMP
FOXTROT
DELTA
FC
LT
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65
67
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71
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74
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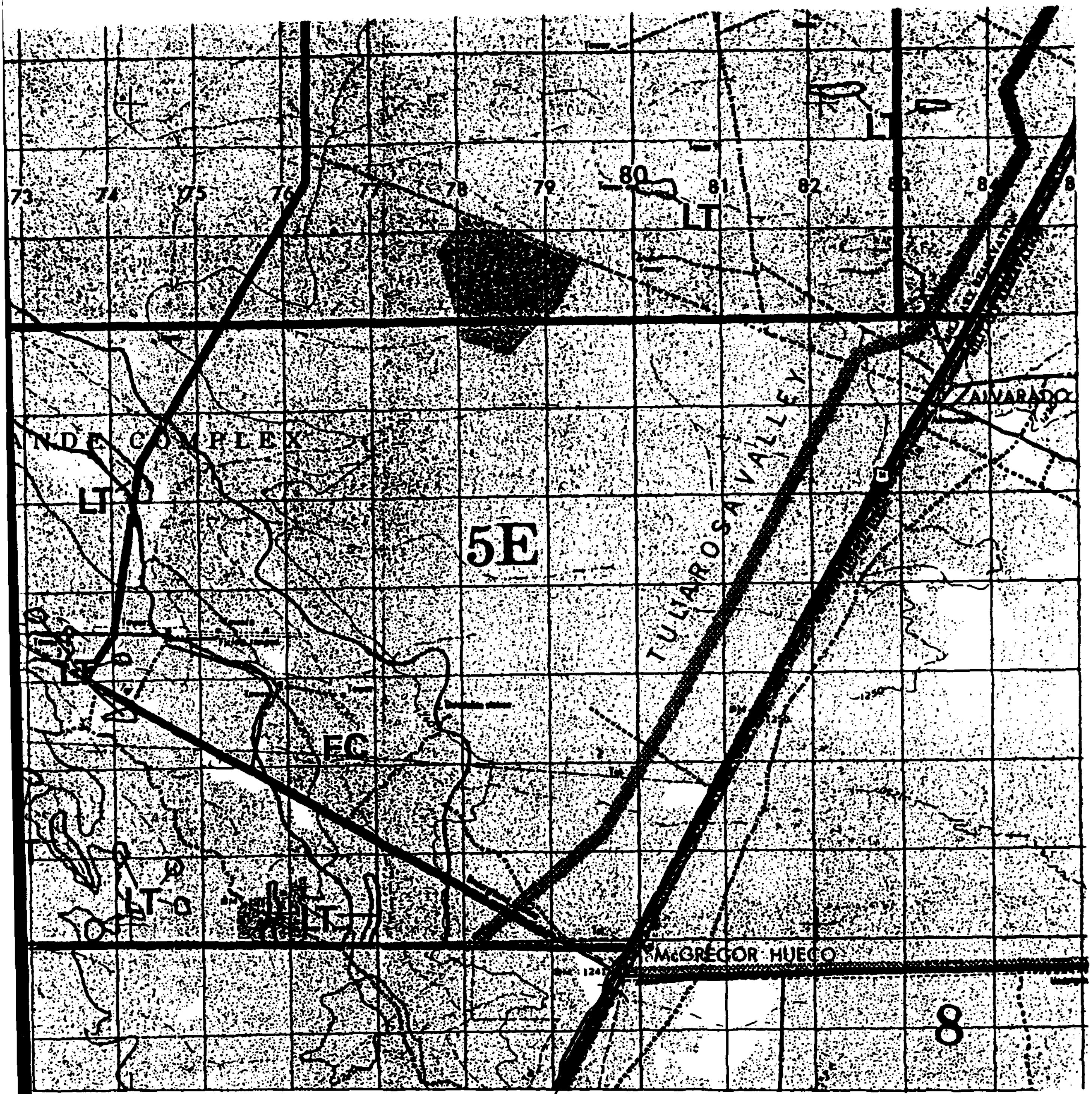
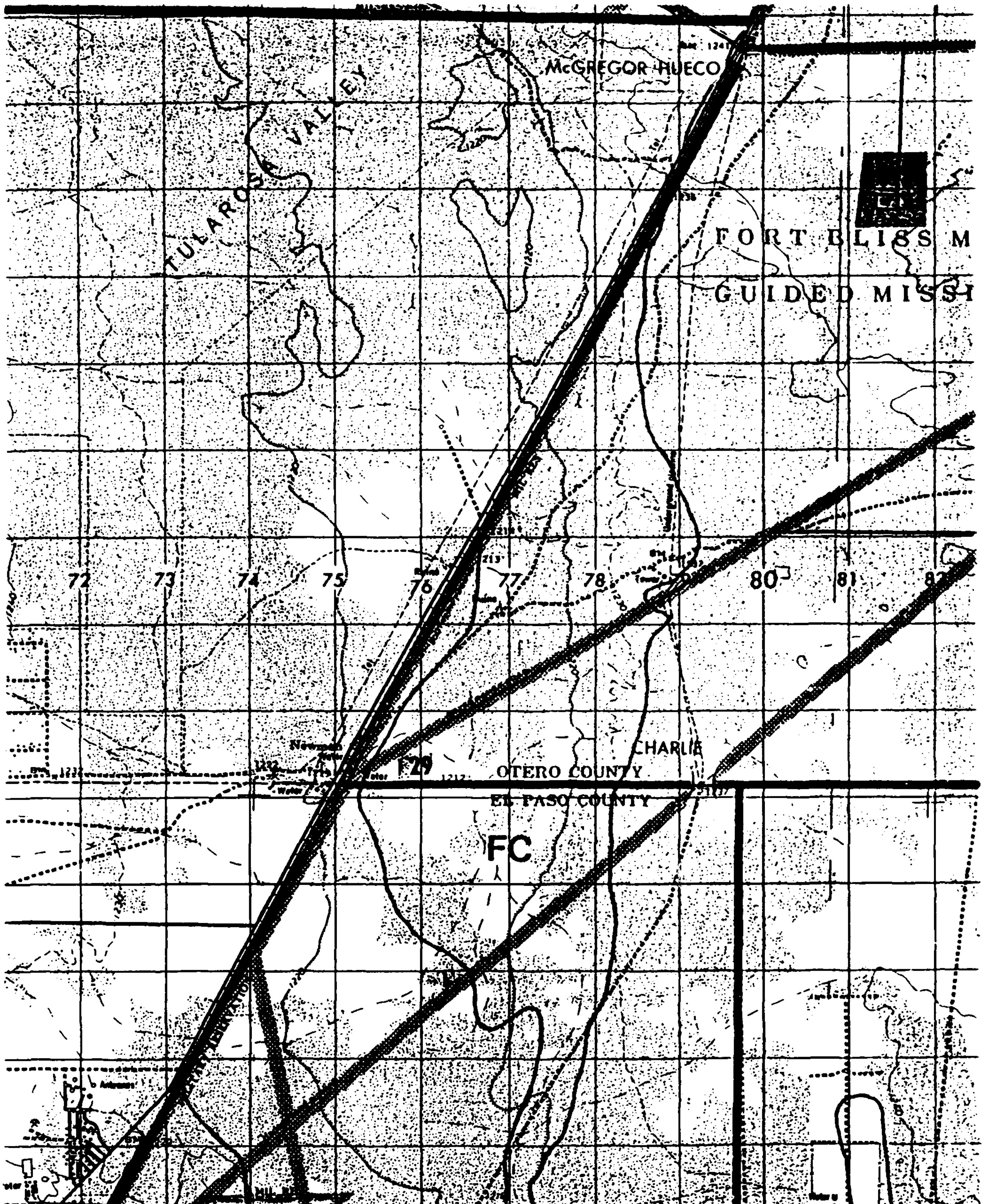
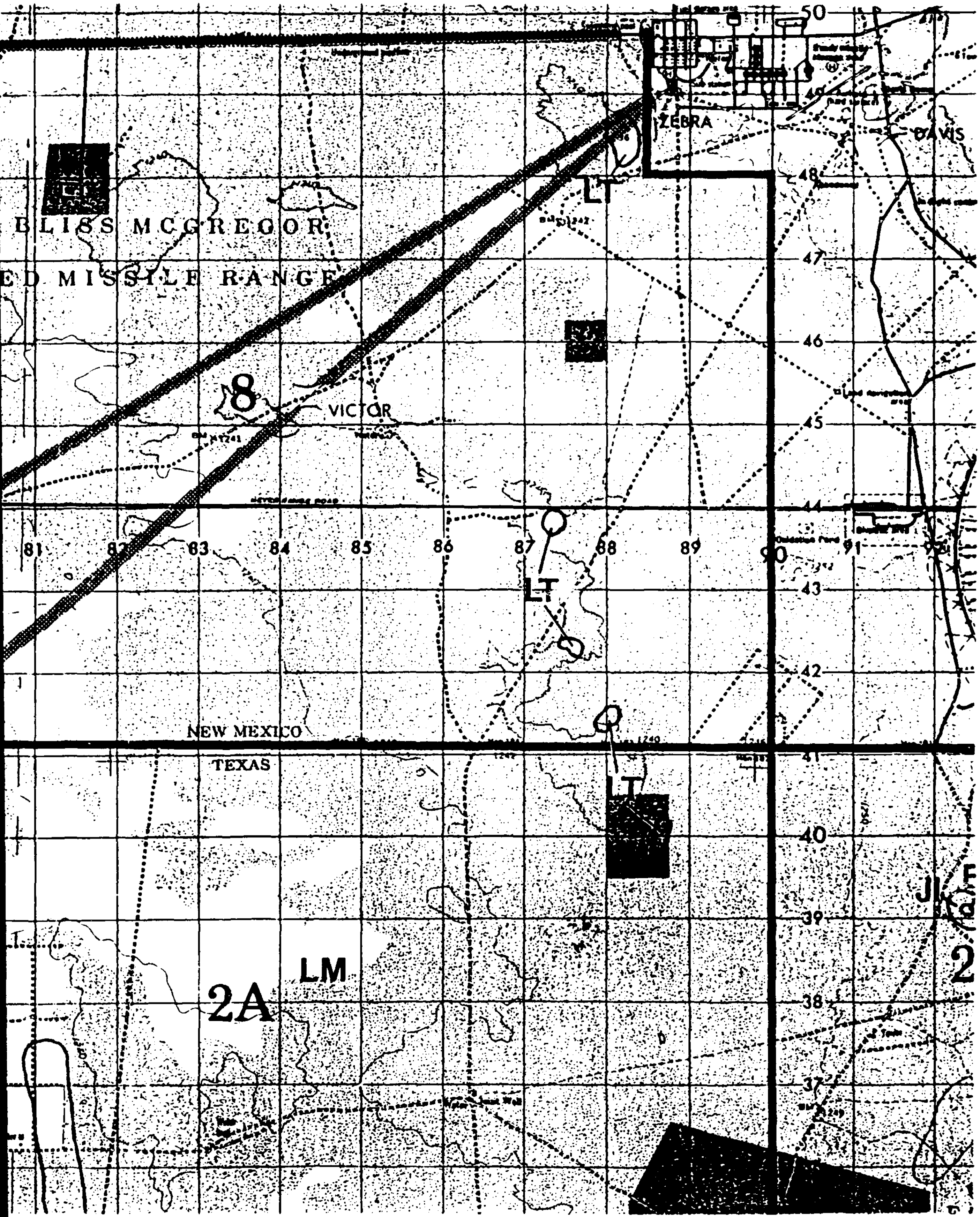
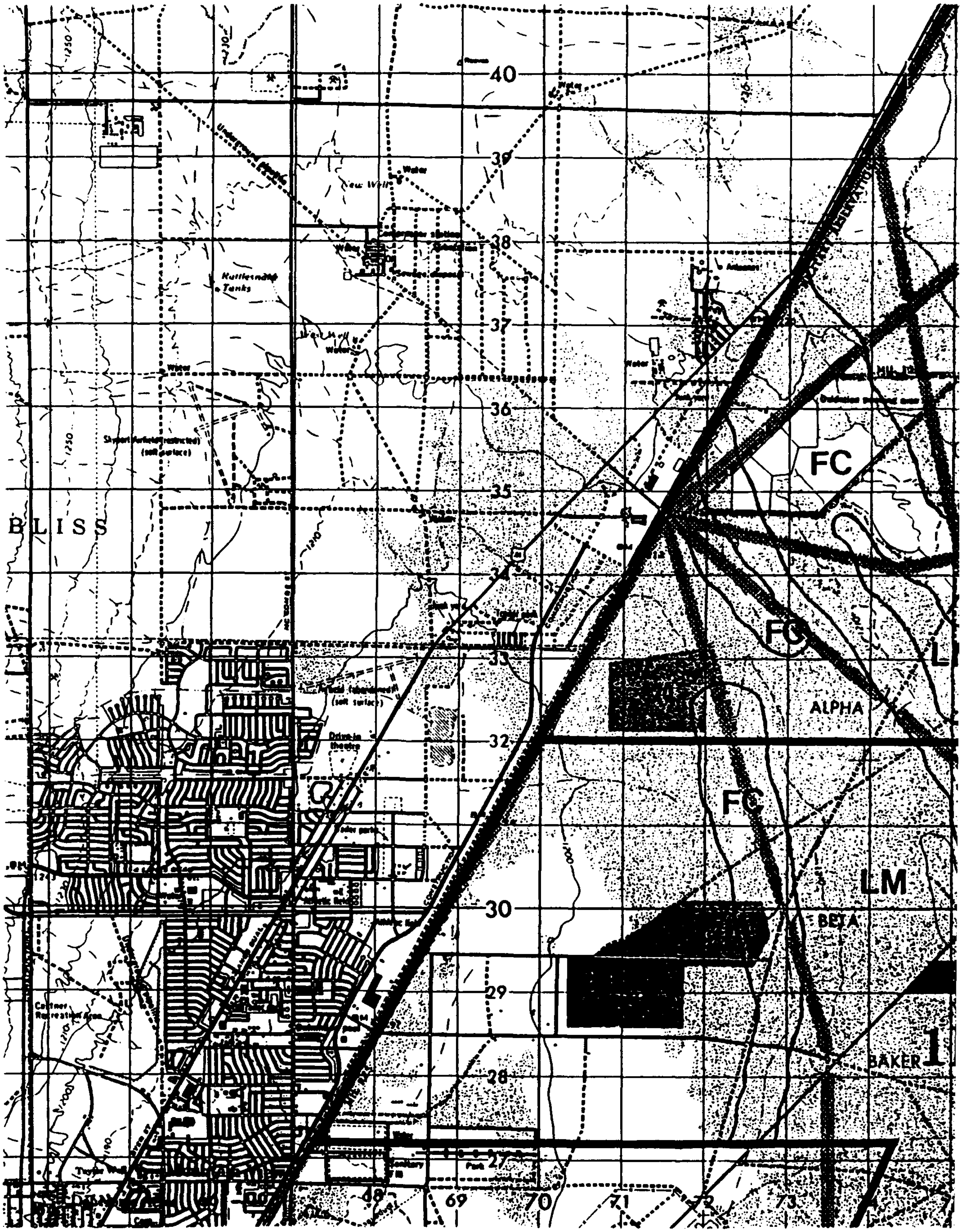
52
51
50

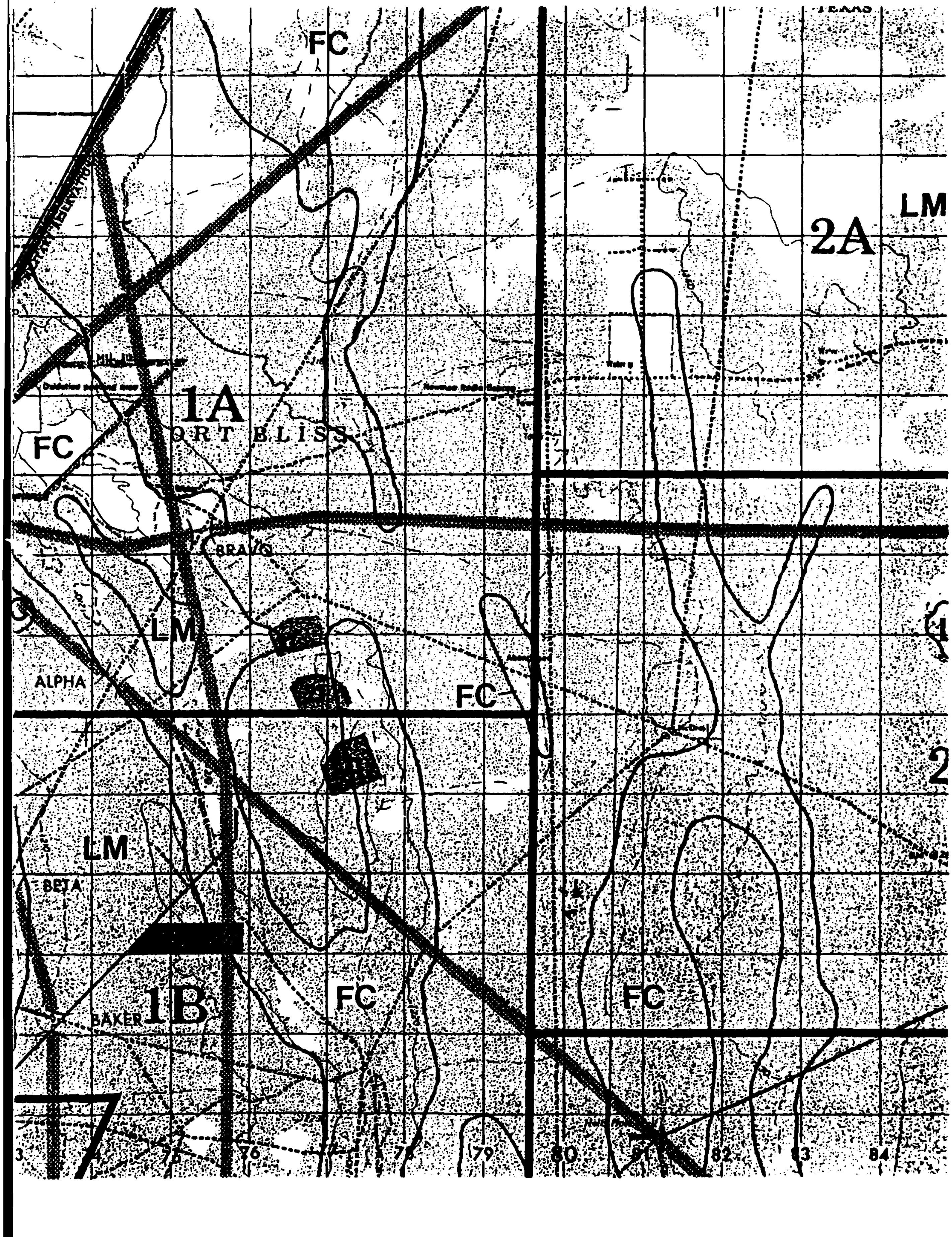

73
74
75
76
77
78
79
80
81
82
LT
5E
TULAROSA VALLEY
ALVARADO
EC
McGREGOR HUECO
8


McGREGOR HUECO
TULAROSA VALLEY
FORT BLISS M
GUIDED MISSI
72
73
74
75
76
77
78
80
81
CHARLIE
F29
OTERO COUNTY
EL PASO COUNTY
FC
1A


ZEBRA
DAVIS
LT
BLISS MCGREGOR
ED MISSILE RANGE
8
VICTOR
81
82
83
84
85
86
87
88
89
90
91
50
48
47
46
45
44
43
42
41
40
39
38
37
LT
NEW MEXICO
TEXAS
LT
2A
LM

1


40
39
38
37
36
35
34
33
32
30
29
28
27
BLISS
Rattlesnake Tanks
Water
Drive-in theatre
FC
FC
FC
ALPHA
BETA
LM
BAKER
1
69
70
71
73


FC
LM
2A
1A
FORT BLISS
FC
BRAVO
LM
ALPHA
FC
LM
BETA
1B
BAKER
FC
FC
75
76
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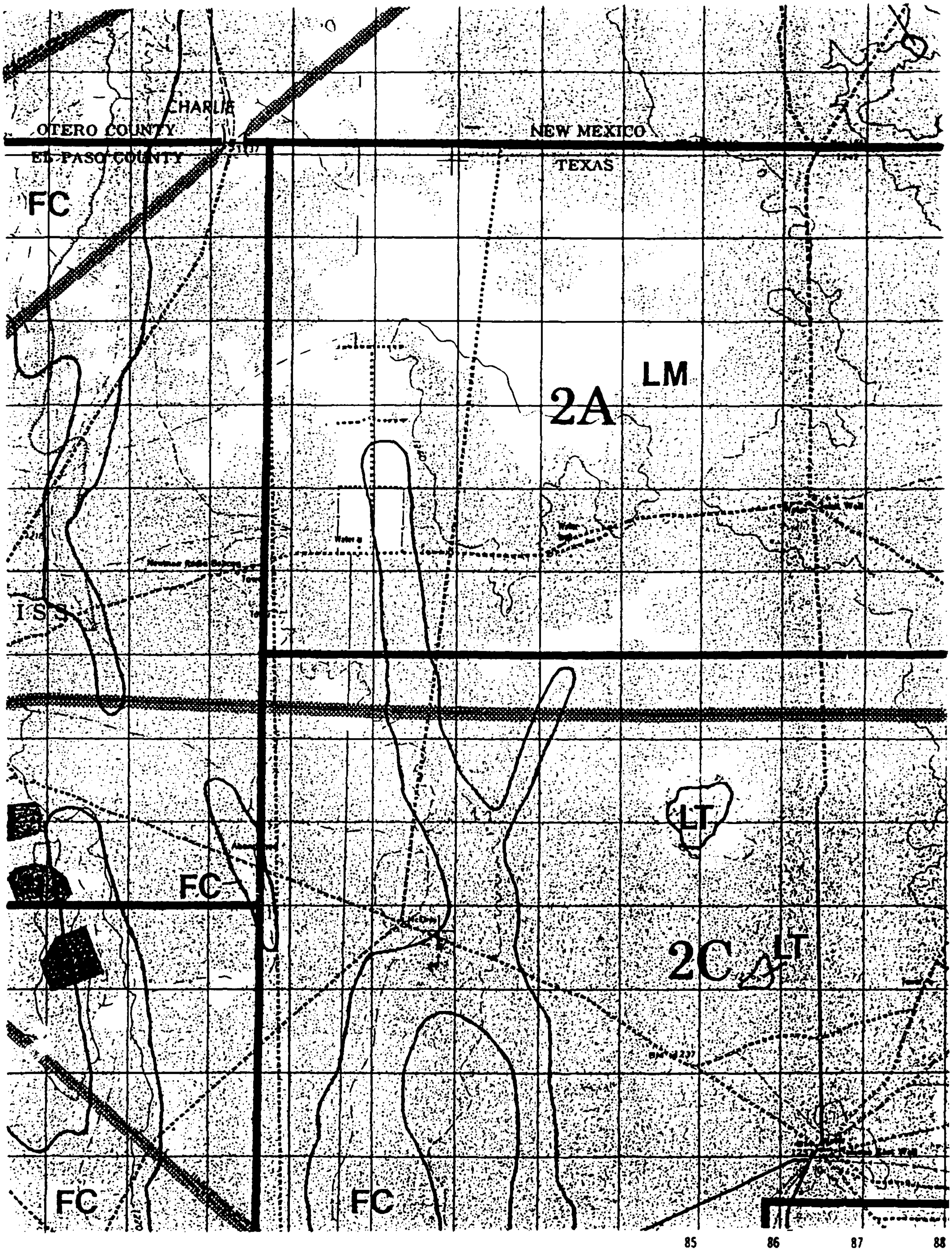
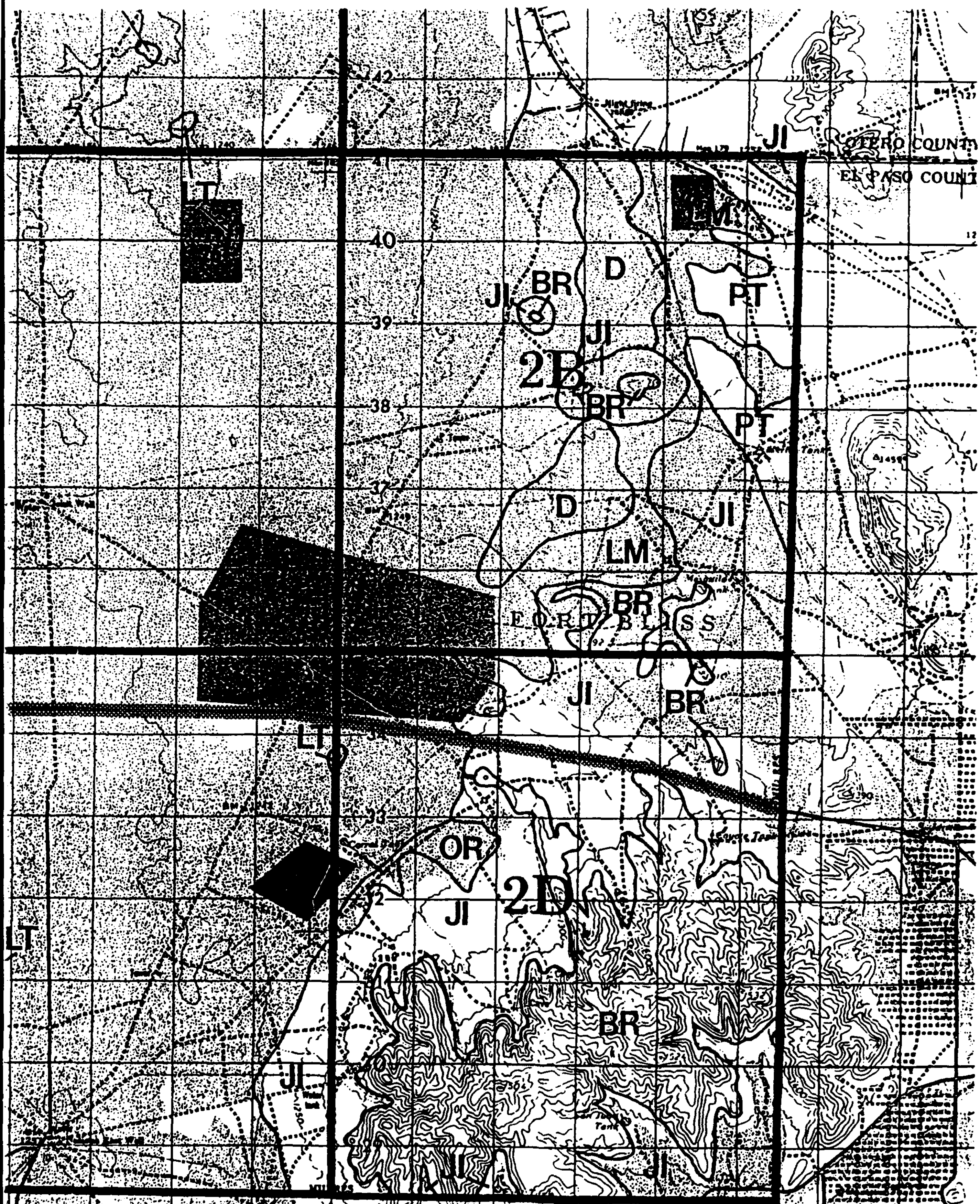
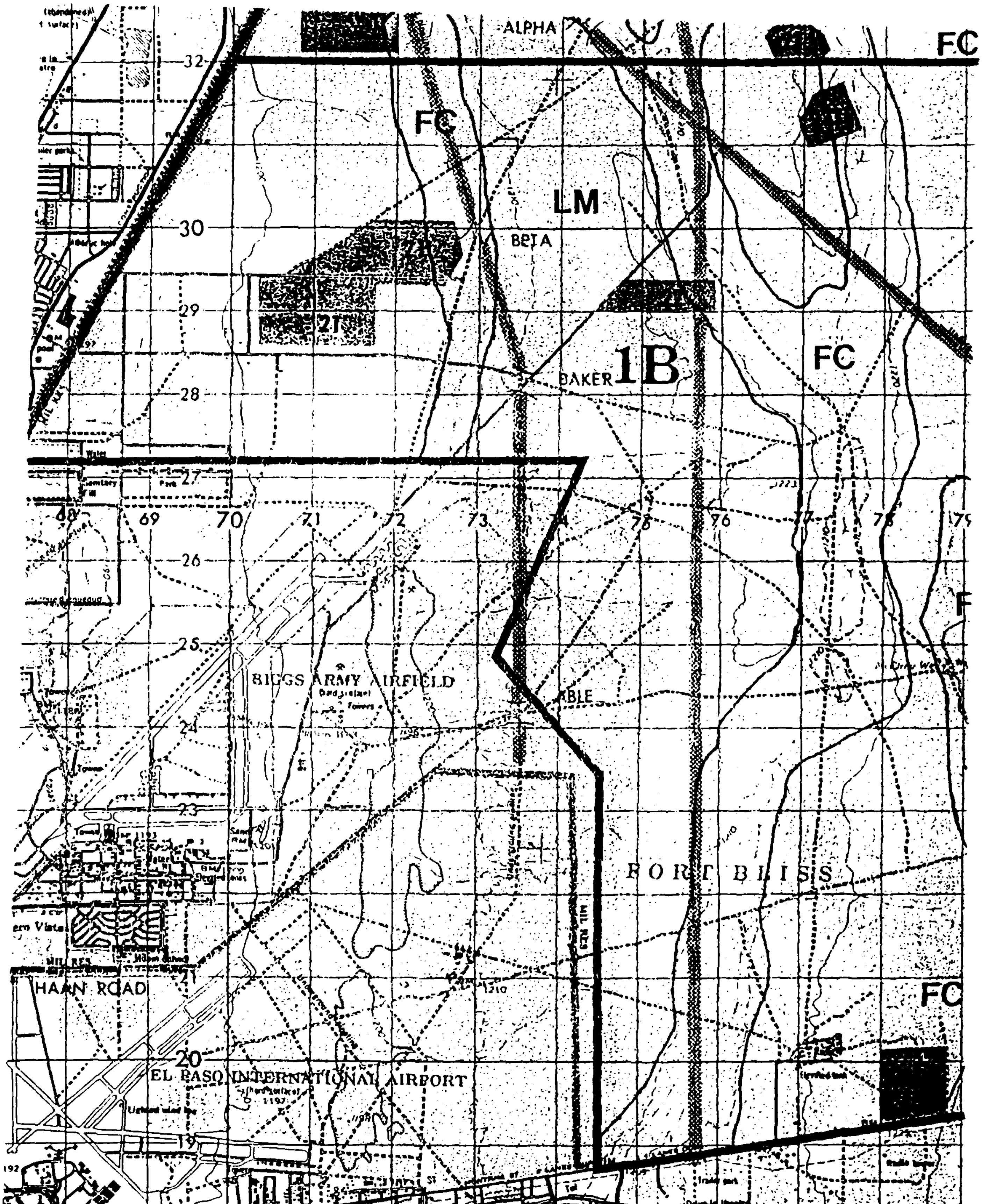
79
80
81
82
83
84


CHARLIE
OTERO COUNTY
EL PASO COUNTY
NEW MEXICO
TEXAS
FC
2A
LM
ISS
LT
FC
2C
LT
FC
FC
85
86
87
88


OTERO COUNTY
EL PASO COUNTY
FORT BLISS
2B
2D
LT
LM
D
BR
JI
PT
OR
87
88
89
90
91
92
93
94
95
96
97

D


ALPHA
FC
FC
LM
BETA
1B
FC
BAKER
27
BIGGS ARMY AIRFIELD
ABLE
FORT BLISS
HAAN ROAD
EL PASO INTERNATIONAL AIRPORT
FC
32
30
29
28
27
26
25
24
23
21
20
19
68
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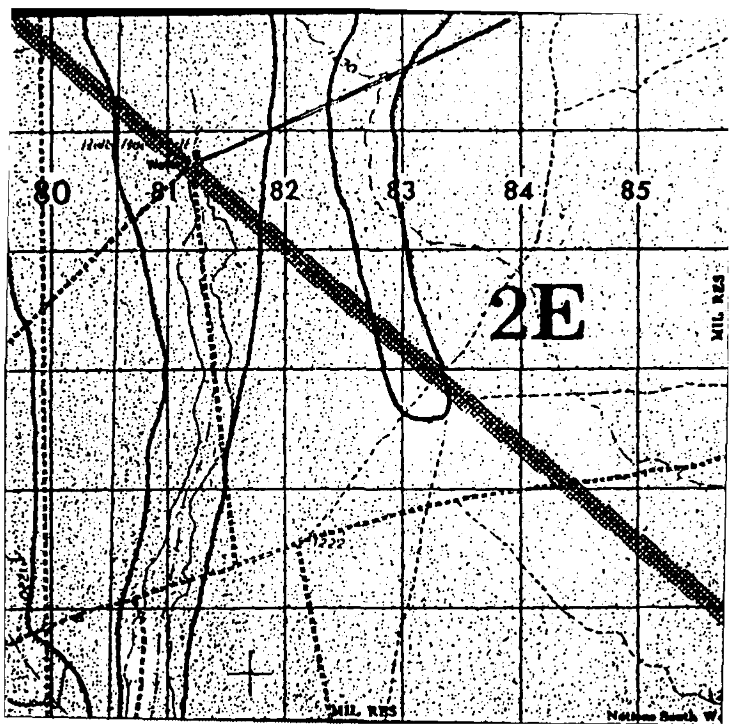
74
75
76
77
78


80
81
82
83
84
85
2E
MIL RES
MIL RES
1222

Chapter IV

EOLIAN ALTERATION OF SOIL STRATA ON MANEUVER AND ADJACENT AREAS OF FORT BLISS

By H. Curtis Monger

The purpose of this investigation was to (1) identify areas where deflation (wind erosion) probably has altered the stratigraphic characteristics of soils causing the archaeological stratigraphy to collapse vertically, and (2) identify areas where deposition may have protected archaeological sites.

Vegetative, topographic, and color patterns of the Fort Bliss land surface were identified on USGS color-infrared aerial photographs (1:58,000) taken in May, June, and September of 1984. The land surface patterns were delineated and related to subsurface features as revealed in backhoe trenches, hand-dug pits, auger holes, and road cuts (see figures I-2 and I-3). The aerial photographs provided high-quality stereo-pair coverage in which even relatively small coppice dunes appeared topographically higher than adjacent deflated interdune areas.

Much of Fort Bliss has been deflated to various degrees and reburied numerous times. As a result, there are many types of soil profiles (see Figure IV-1). Four mapping units were devised to group soils in a manner reflecting deflational and depositional characteristics. Mapping Unit I includes deflated dune and nondune areas exposed at the modern land surface. Mapping Unit 2 includes areas buried by historical blowsand in the form of dunes with interdune sheet deposits. Mapping Unit 3 is similar to Mapping Unit 2 except the historical blowsand occurs as large sheet deposits. Mapping Unit 4 includes areas that have been modified little by wind activity because soils have been protected by an armor of desert pavement or high clay content.

Mapping Unit 1: Modern Deflational Surfaces

This mapping unit [illegible] areas of the modern land surface that have been deflated. These areas were identified by the occurrence of lag layers of indurated caliche fragments, which indicates a deflated soil profile (see Figure IV-1). Generally these areas are not buried, or are buried by less than approximately 30 cm of eolian sediments. This mapping unit occurs in patches and most commonly is associated with fault scarps and areas where tank traffic has been extensive. Mapping Unit 1 is similar to the mapping unit "Zone 1" of Davis and Nials (1988) in their study of the Santa Teresa area in south-central New Mexico.

Caliche fragments, which are diagnostic for this mapping unit, are composed of stage II carbonate nodules and petrocalcic horizon fragments. The lag accumulation of these nodules signifies the deflational destruction of a former soil profile containing this material and the vertical collapse of the nodules. Petrocalcic horizon fragments accumulate on the land surface as the result of a La Mesa soil being truncated by deflation. Petrocalcic horizons, however, need not be exhumed totally before fragments begin accumulating on the land surface. Soil profile exposures in many Fort Bliss locations reveal petrocalcic horizons begin to disintegrate when they are about 40 cm from the surface as the result of root and wetting front penetration. Once released, fragments of the petrocalcic horizon begin an upward migration to the land surface.

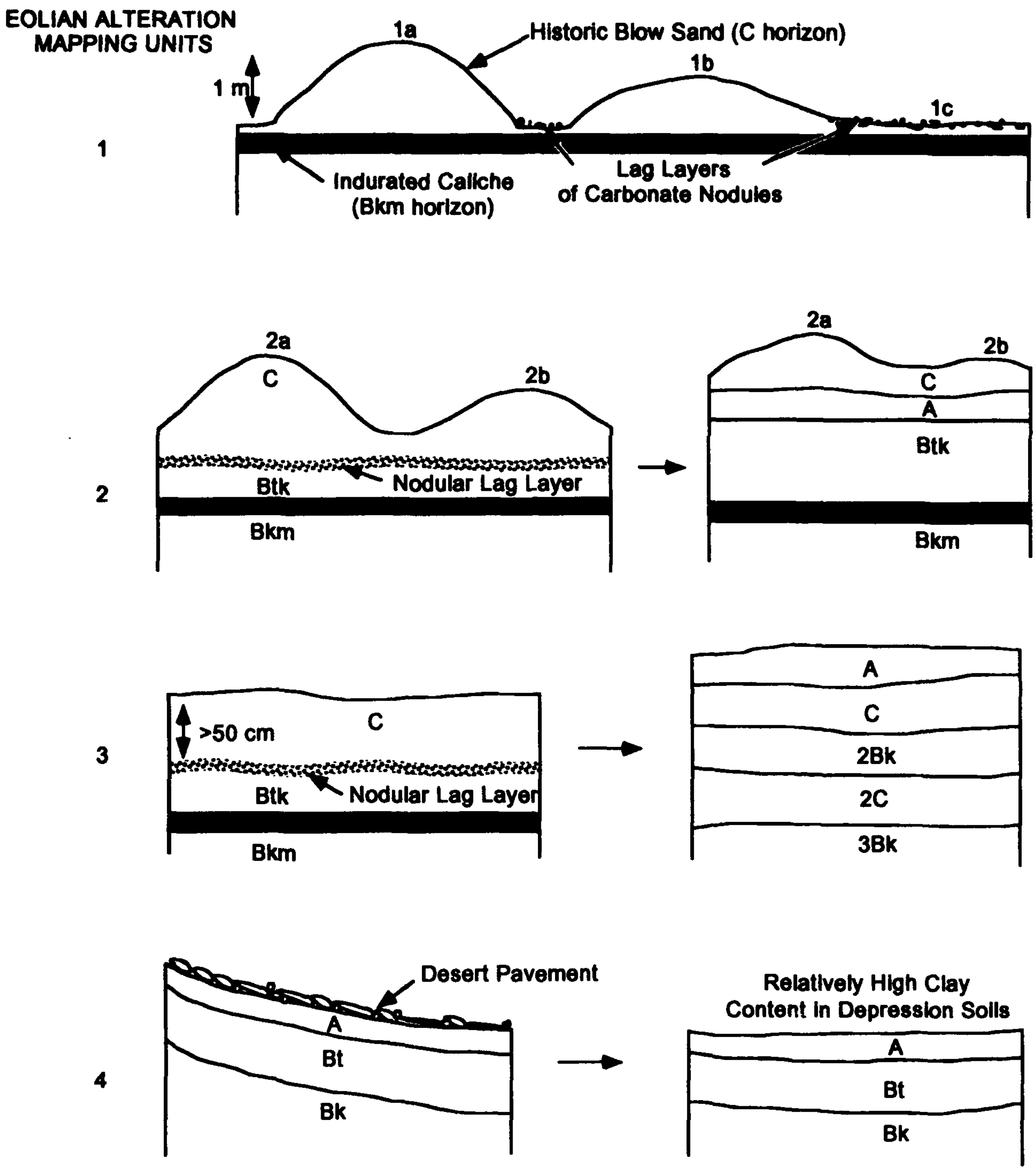


Figure IV-1. Eolian Alteration Mapping Unit Soil Profiles
(Soil horizon nomenclature is that used by the U.S. Cooperative Soil Survey–Soil Survey Staff 1992.)

(1a): Large Dunes (generally greater than 1 m) with Collapsed Interdune Strata

This mapping unit occurs to a minor extent on both Fort Bliss North and South. Many areas of 1a in Fort Bliss North appear white on aerial photographs. The large dunes generally have little interdune vegetation.

(1b): Small Dunes (generally less than 1 m) with Collapsed Interdune Strata

This mapping unit is similar to Mapping Unit 1a except dunes here are smaller. These areas generally have some interdune vegetation and commonly are associated with areas of faulting and tank traffic.

(1c): Deflated Nondune Areas

These are deflated areas that do not contain dunes. These areas often are disturbed by land use and commonly contain a snakeweed cover.

Mapping Unit 2: Dunes with Interdune Sheet Deposits

Mapping Unit 2 is the most extensive type of eolian alteration unit on both Fort Bliss North and South. This unit is composed of historical blowsand in the form of dunes with interdune sheet deposits. It is subdivided into units 2a (dunes generally greater than 1-m high) and 2b (dunes less than 1-m high). These historical eolian deposits bury landscapes containing soils that have undergone various degrees of deflation (see Figure IV-1). On one extreme, historical blowsand covers paleodeflational surfaces in which archaeological stratigraphy would have collapsed. In contrast, many buried landscapes have undeflated soil profiles in which archaeological stratigraphy would be intact.

In a study area west of the Jarilla Mountains, Blair et al. (1990) described the various thicknesses of historical eolian deposits. Their fence diagram illustrates that in most cases historical blowsand overlies Holocene Organ material. The same is true for large areas on Fort Bliss.

Good profile exposures of Mapping Unit 2 occur along Area 8's southern boundary (a road). Much of the northeastern section of Fort Bliss North is covered with Mapping Unit 2a, in which dunes are aligned in a northeast-southwest direction. Mapping Unit 2 is similar to Mapping Unit "Zone 3" of Davis and Nials (1988).

(2a): Large Dunes (generally greater than 1 m) with Interdune Sheet Deposits

Wind ripples are common in this unit and indicate active sand movement. Interdune vegetation is sparse.

(2b): Small Dunes (generally less than 1 m) with Interdune Sheet Deposits

This mapping unit is transitional between mapping units 2a and 3. Dunes here generally are smaller than 1 m in height. Interdune grasses are common.

Mapping Unit 3: Depositional Areas Composed of Sand Sheet Deposits

Many areas of Fort Bliss, especially the grassland areas, are buried by sheet deposits of historical eolian deposits. These sheet deposits cover both deflated land surfaces and areas that have intact soil stratigraphy (see Figure IV-1). Mapping Unit 3 is similar to Mapping Unit "Zone 2" of Davis and Nials (1988).

Mapping Unit 4: Areas Where Soil Strata Are Modified Little by Wind

Many of the fan-piedmont and depressional basin floor areas contain soils modified little by wind activity. The fan-piedmont soils commonly are protected by an armor of desert pavement (see Figure IV-1). Depression soils in the basin floor generally have higher clay concentrations than do neighboring soils. Apparently the clay protects these soils from wind erosion.

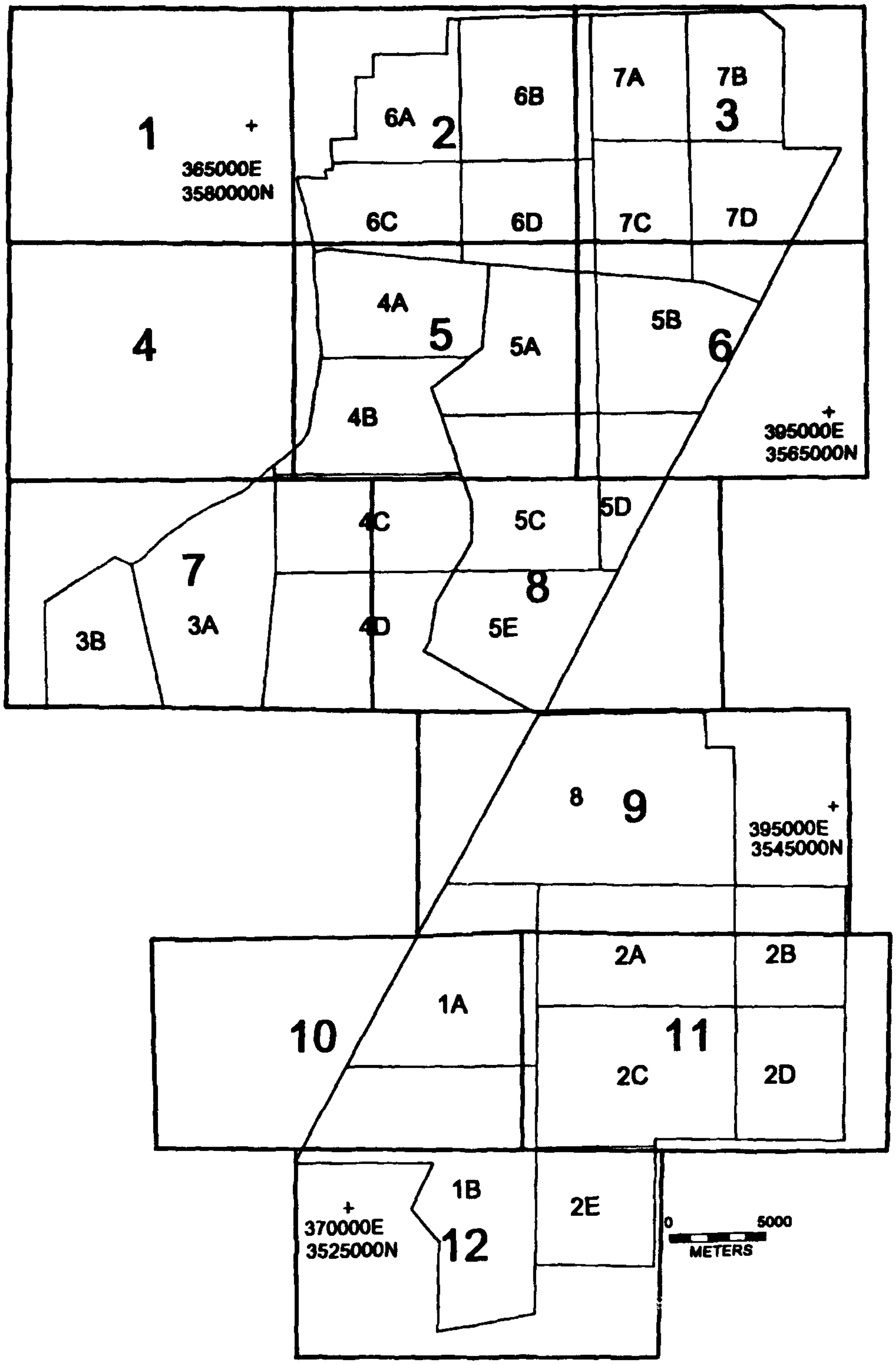


Figure IV-2. Index Map of Soil Strata Eolian Alteration

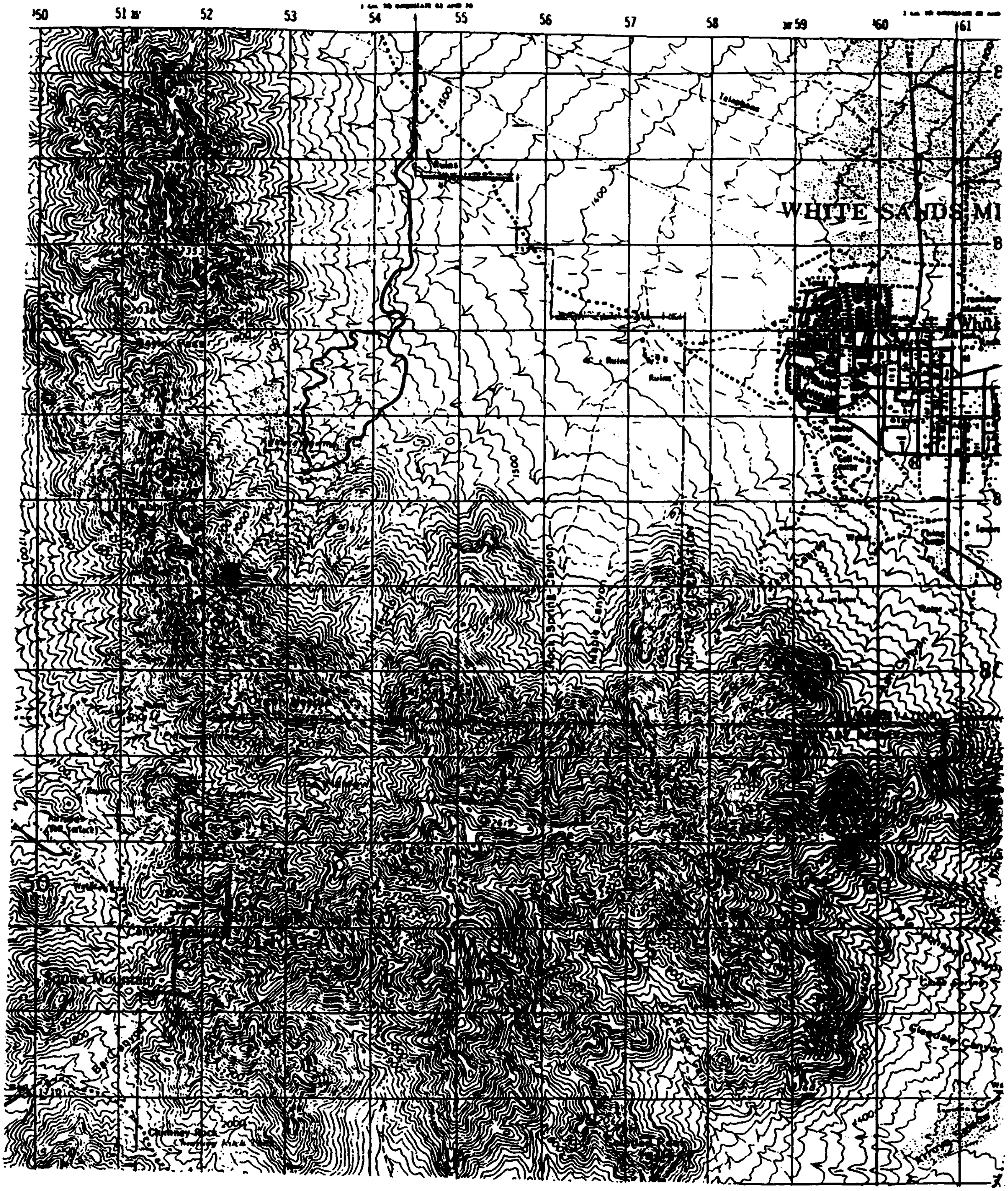
Map Legend:

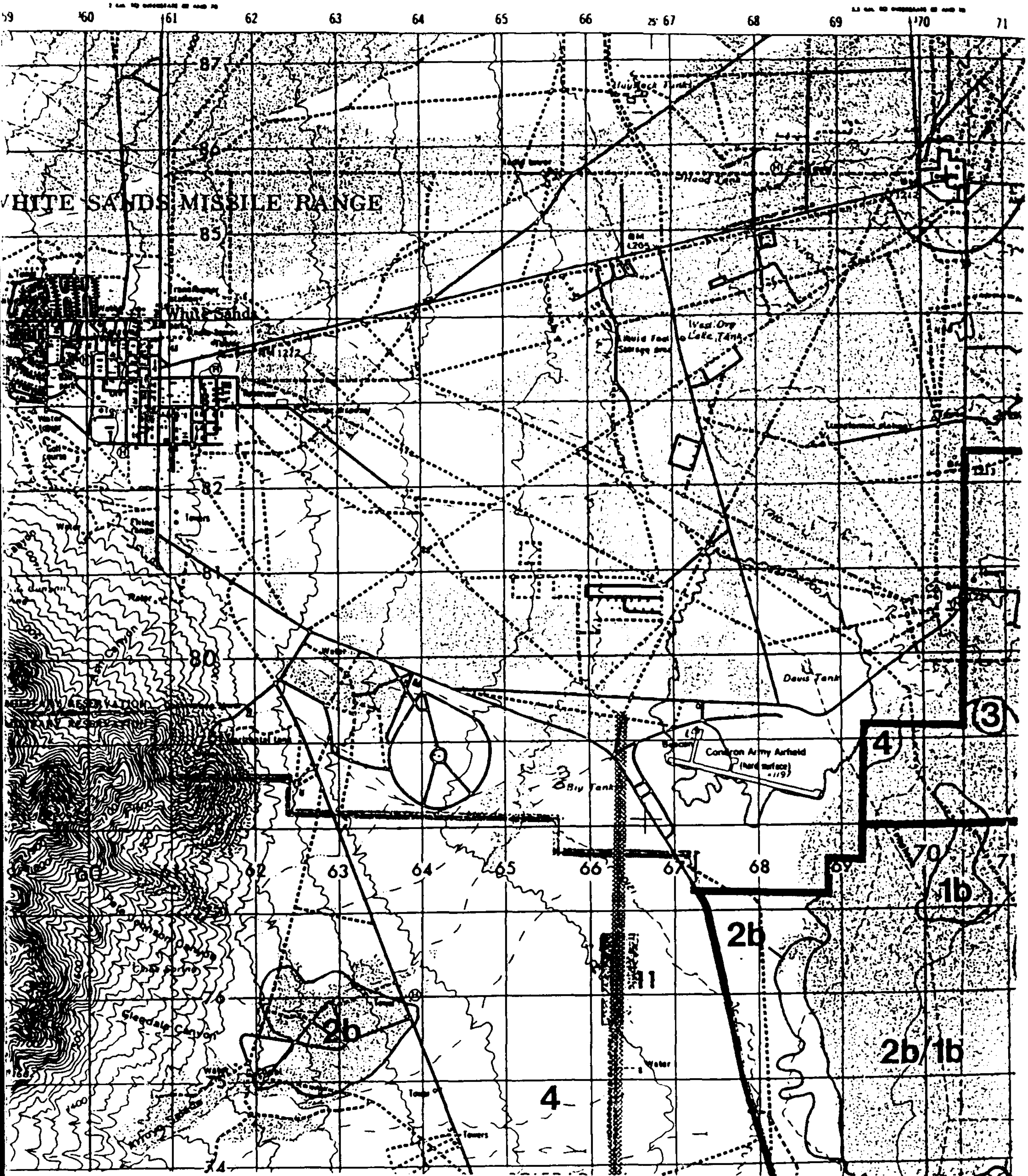
The following symbols, described earlier in this chapter, were used to indicate the various categories of soil strata eolian alteration.

Symbol	
1a	See text in this chapter for descriptions
1b	See text in this chapter for descriptions
1c	See text in this chapter for descriptions
2a	See text in this chapter for descriptions
2b	See text in this chapter for descriptions
3	See text in this chapter for descriptions
4	See text in this chapter for descriptions

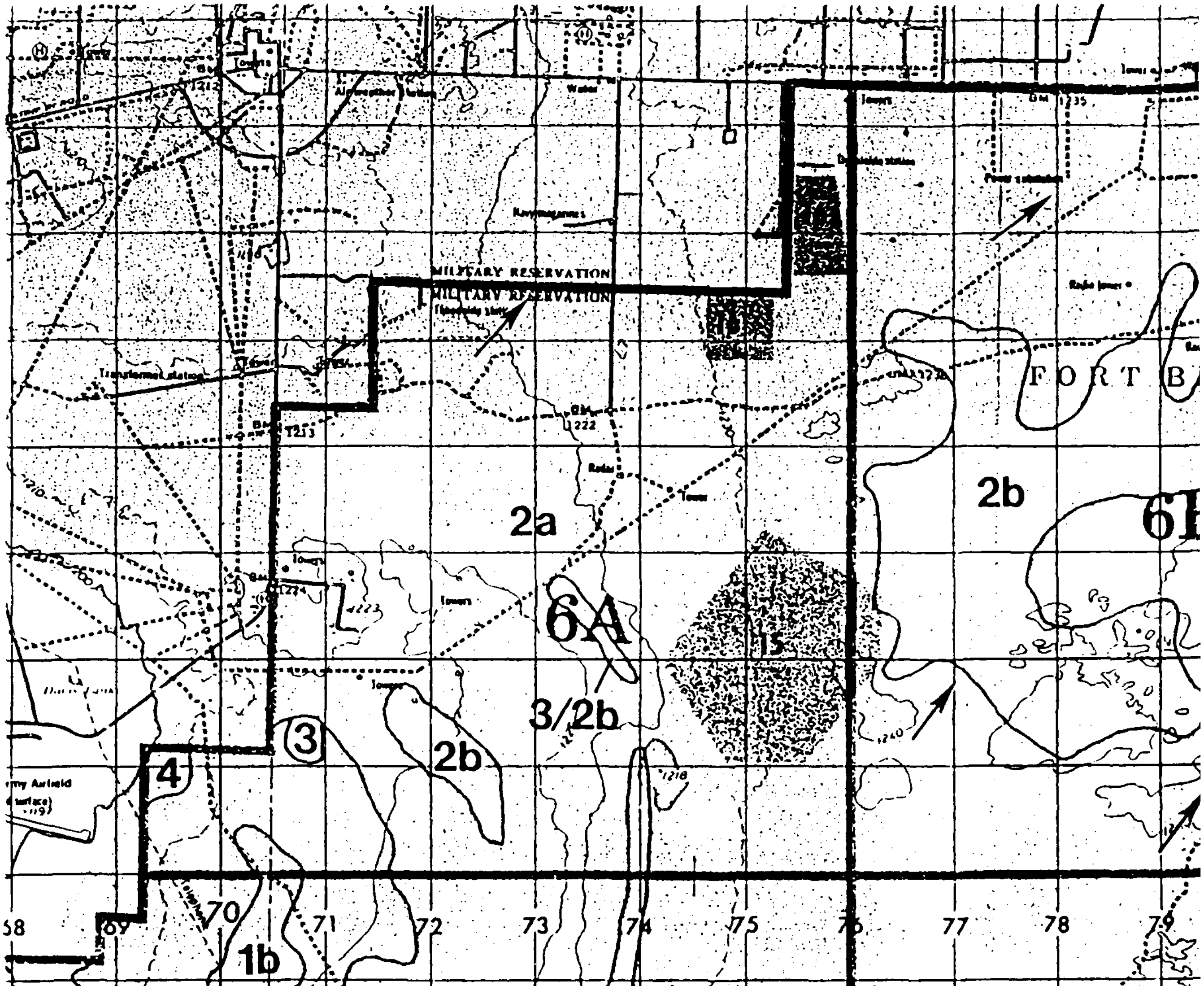
Areas that have an intricate association of two or more mapping units are signified by combining the symbols, such as 1a/2a. The preceding symbol indicates the dominant mapping unit. Arrows indicate locations where coppice are aligned and the direction of alignment. Arrows pointing NE do not necessarily imply movement in that direction.

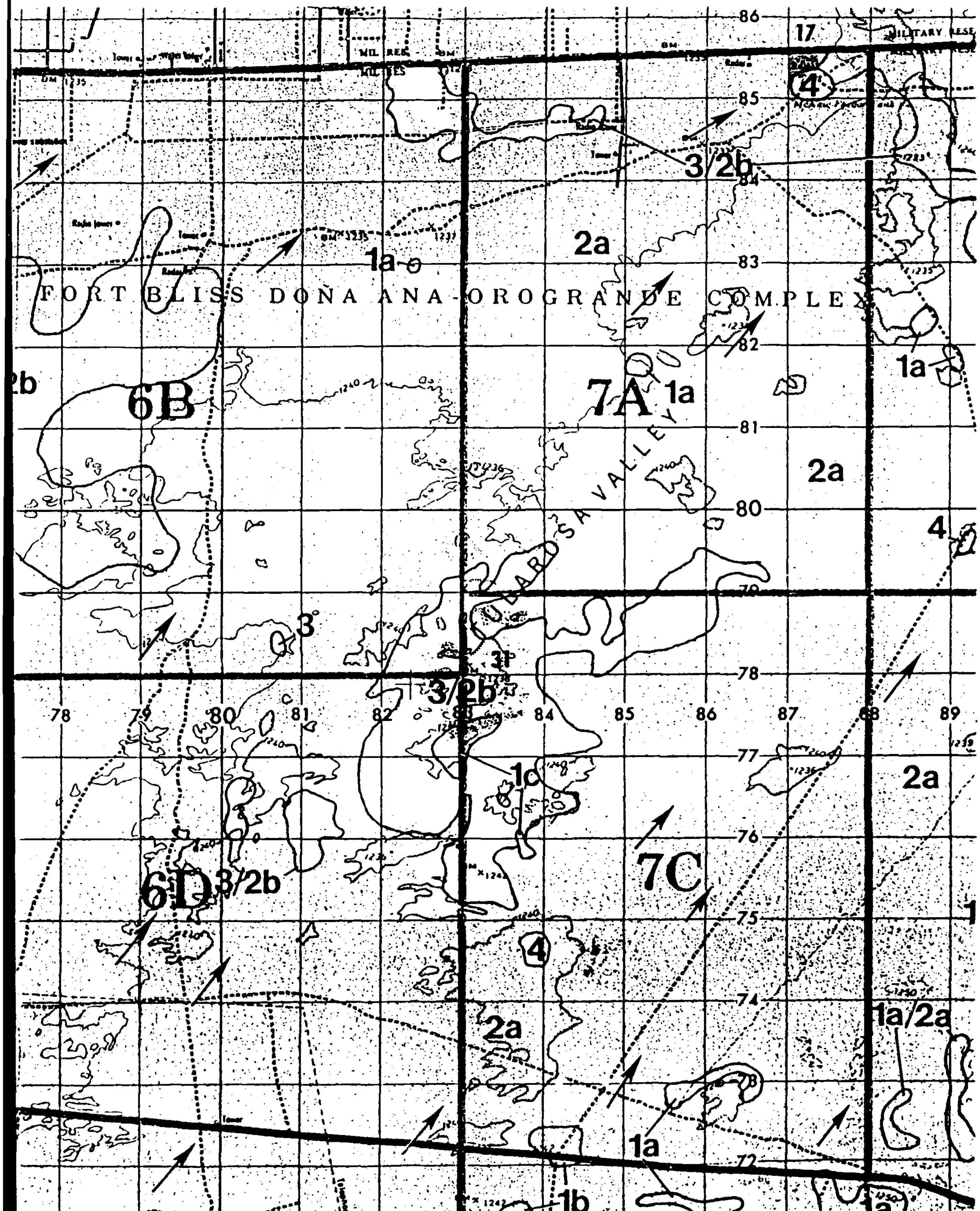
1

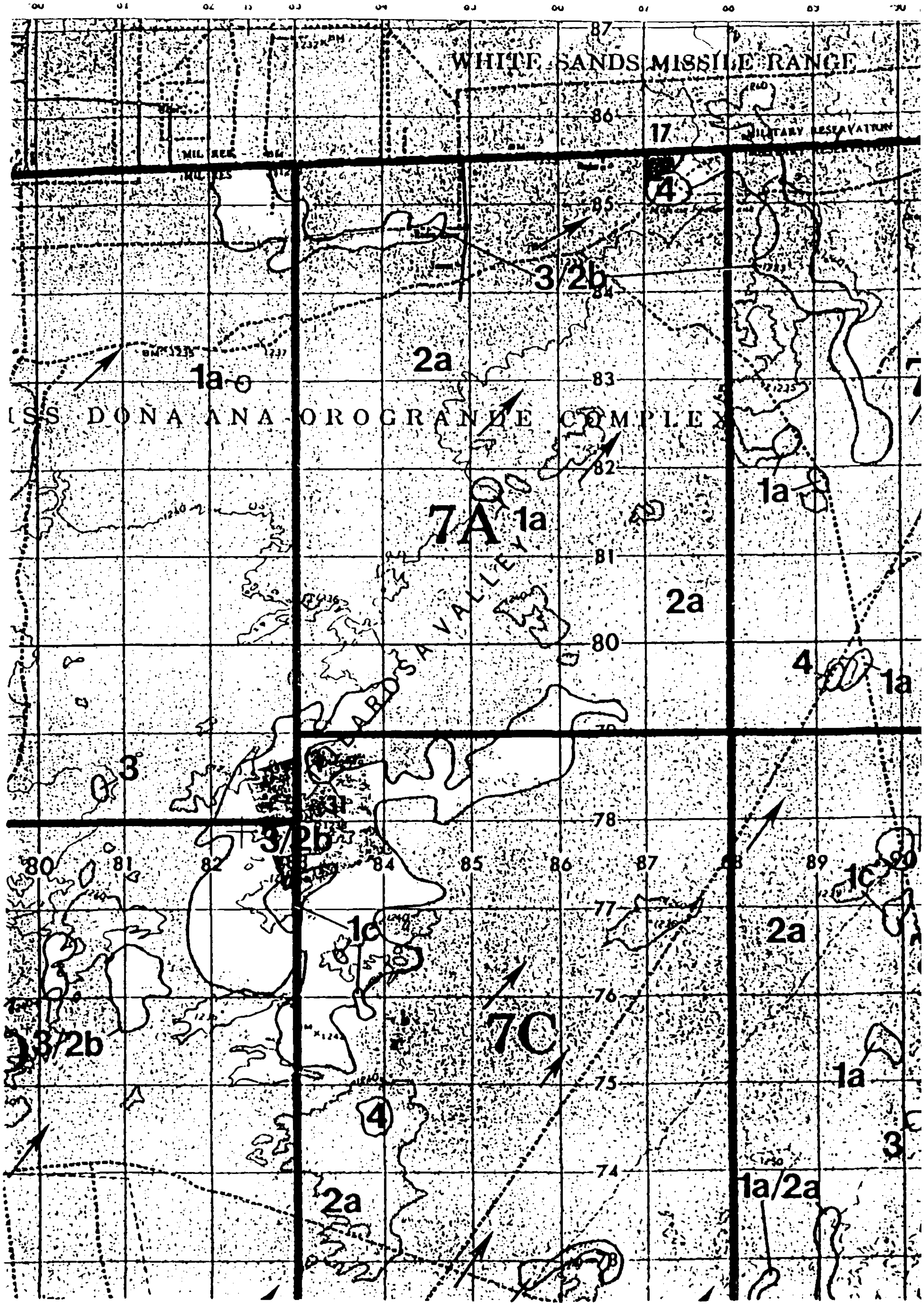

50
51
52
53
54
55
56
57
58
59
60
61
WHITE SANDS MI
1500
1600
Ruins
Chimney Rock


59
60
61
62
63
64
65
66
67
68
69
70
71
HITE SANDS MISSILE RANGE
87
86
85
82
81
80
76
74
White Sands
Hood Tank
Davis Tank
Big Tank
Condron Army Airfield
(hard surface)
Towers
Water
3
4
1b
2b
11
2b/1b

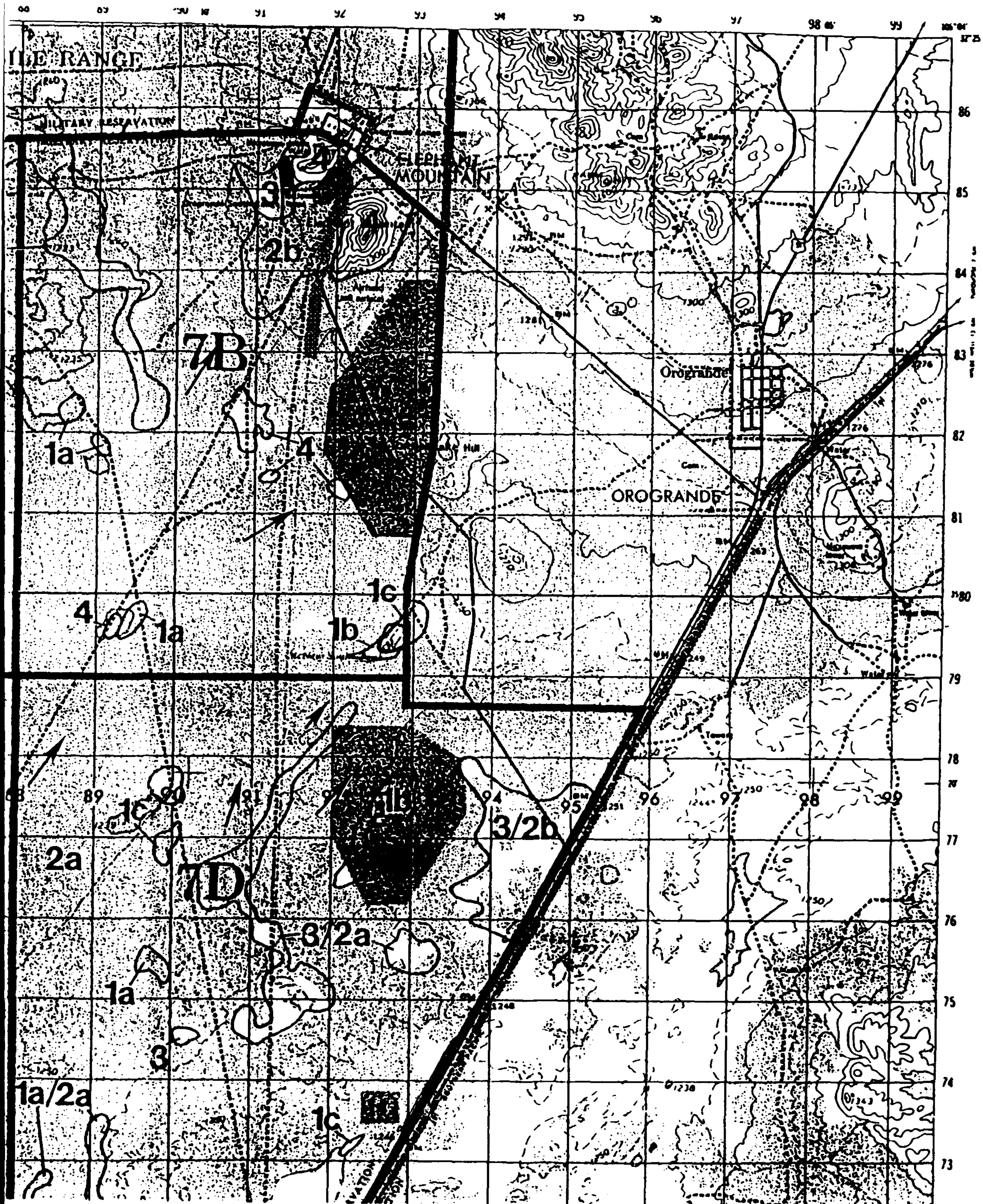
1


MILITARY RESERVATION
MILITARY RESERVATION
FORT B
2a
2b
6A
3/2b
15
3
4
2b
1b
2a
6C
2b/1b
1b
2b
68
69
70
71
72
73
74
75
76
77
78
79
Telephone
Transformer station
Radar
Towers
Army Airfield

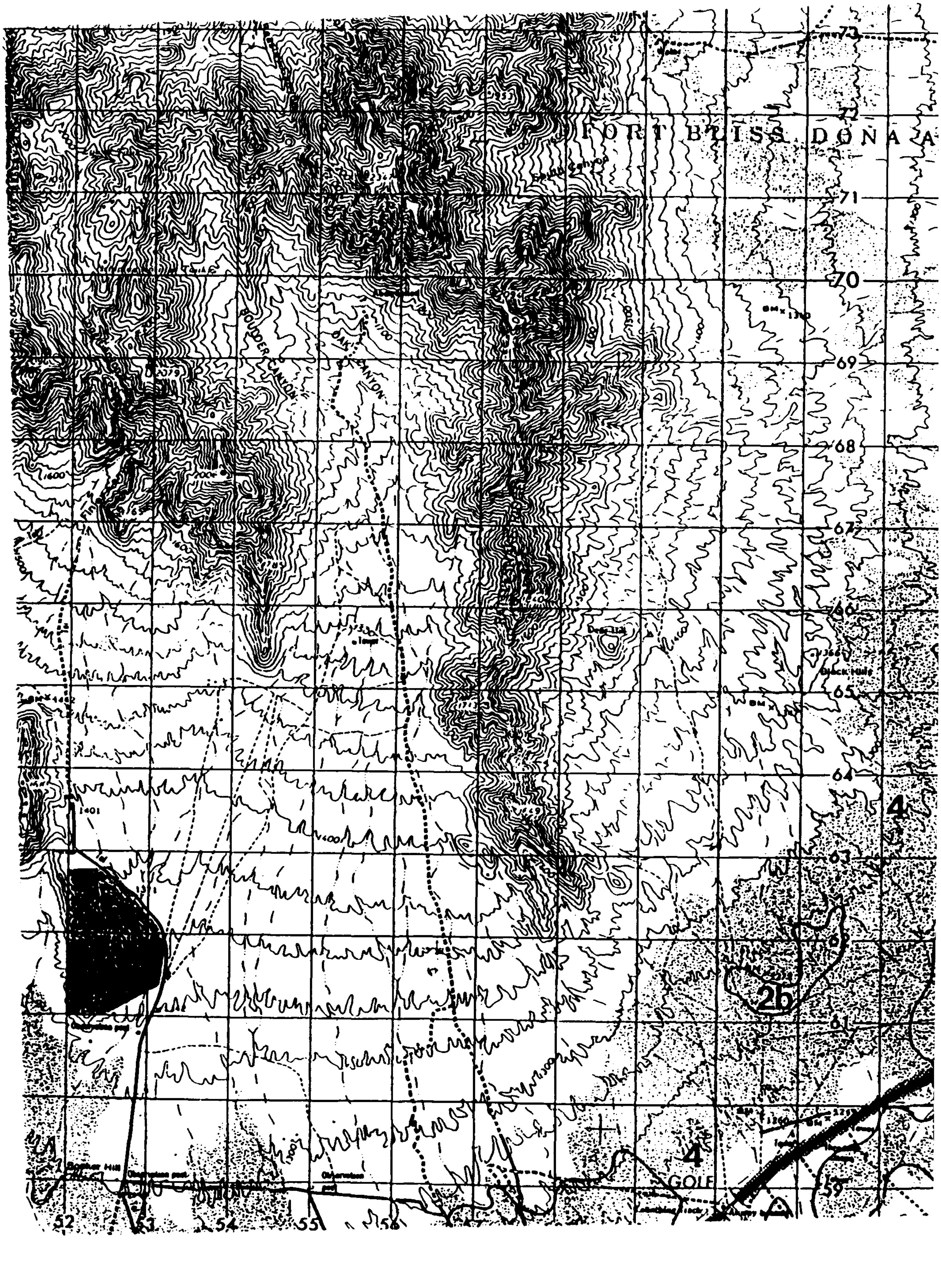

FORT BLISS DOÑA ANA-OROGRANDE COMPLEX
6B
6D
7A
7C
2a
1a
1b
1c
3
3/2b
4
1a/2a
2b
17



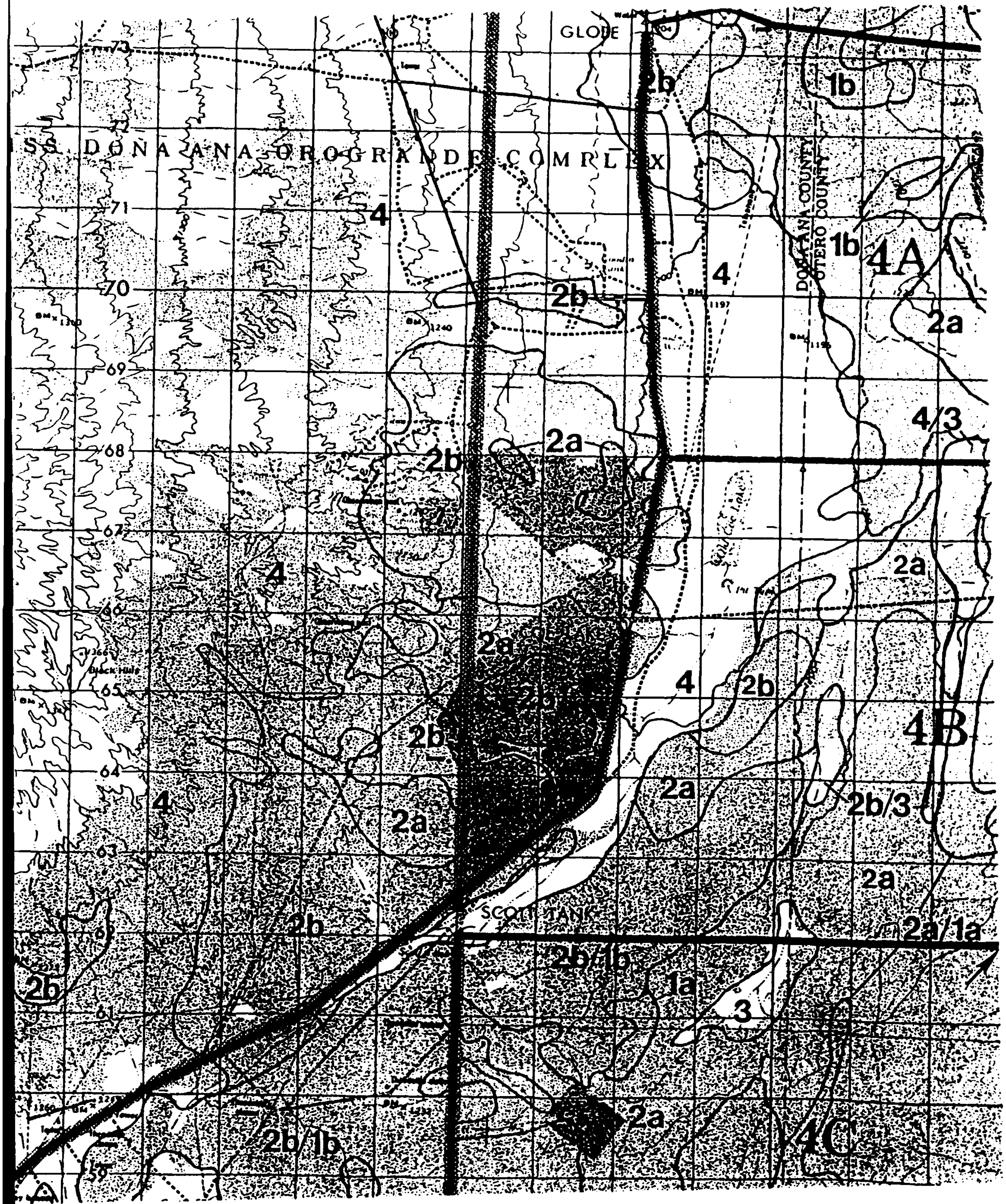
WHITE SANDS MISSILE RANGE
MILITARY RESERVATION
DONA ANA-OROGRANDE COMPLEX
VALLEY
7A
7C
1a
1c
2a
3/2b
3
4
17
20
1a/2a

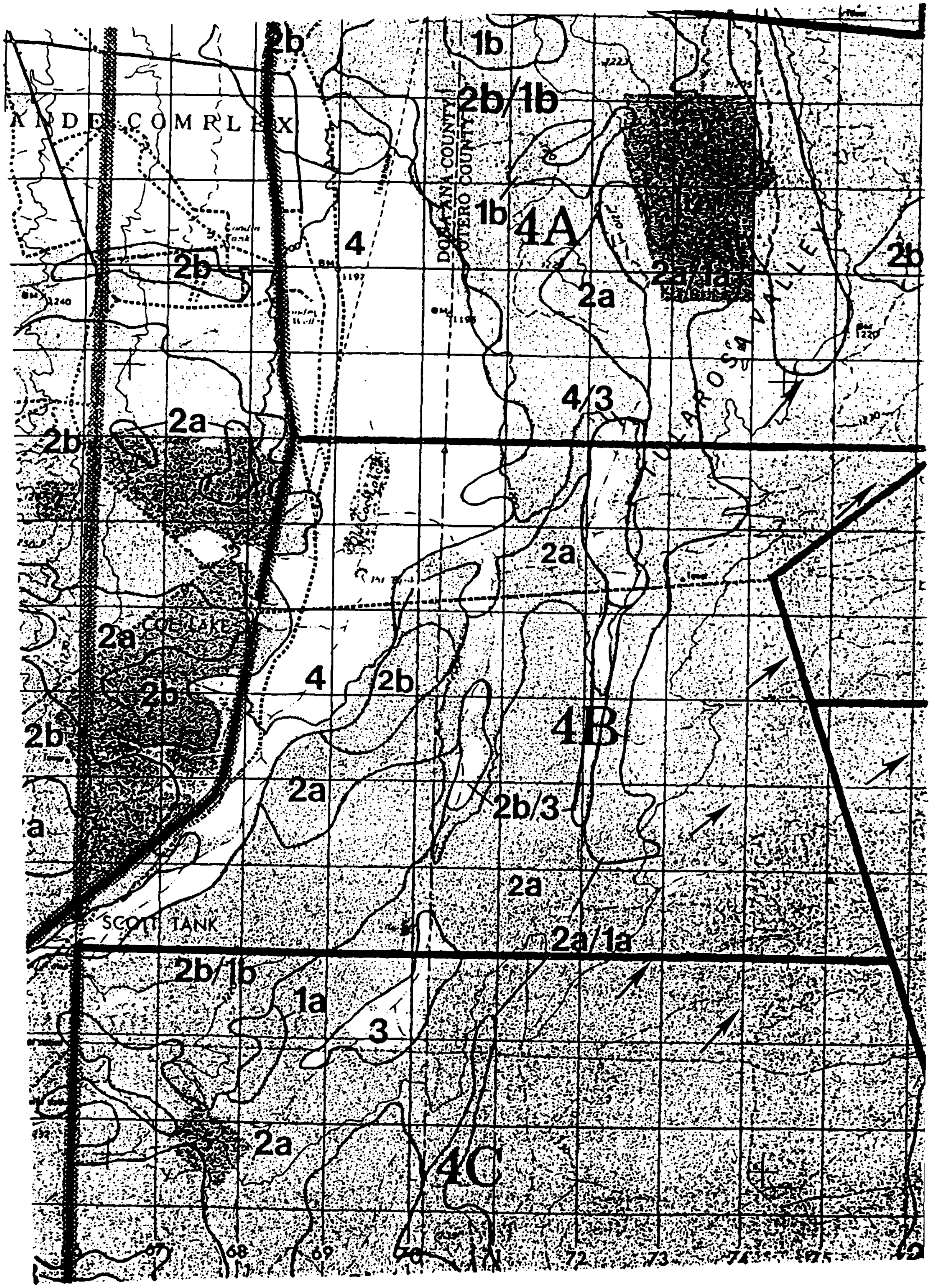


MILITARY RESERVATION
ELEPHANT MOUNTAIN
Orogrande
OROGRANDE
7B
7D
1a
1b
1c
2a
2b
3
4
3/2a
3/2b
1a/2a

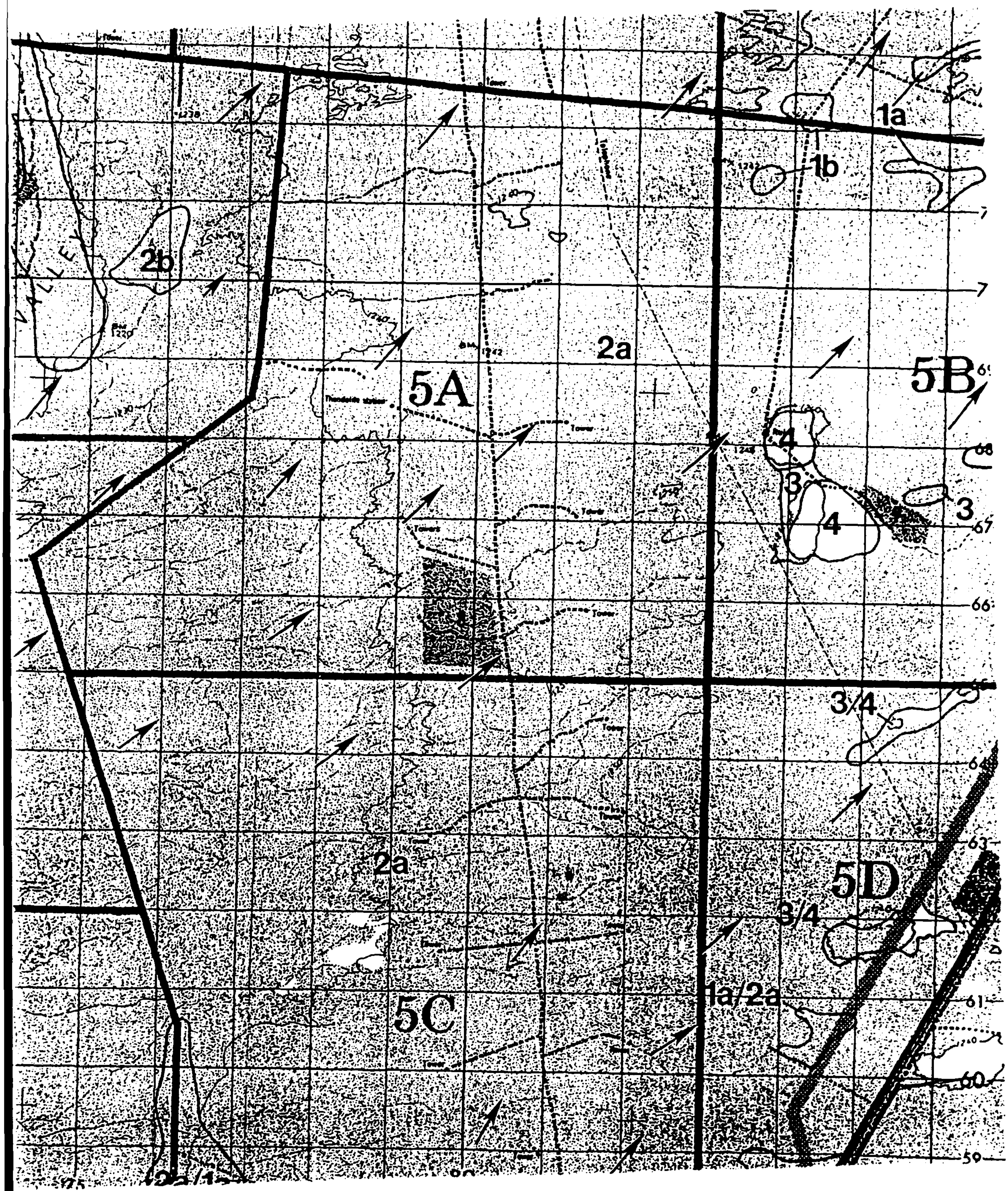


FORT BLISS DOÑA A
BOULDER CANYON
Black Hills
GOLF
4
2b
52
53
54
55
56
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73

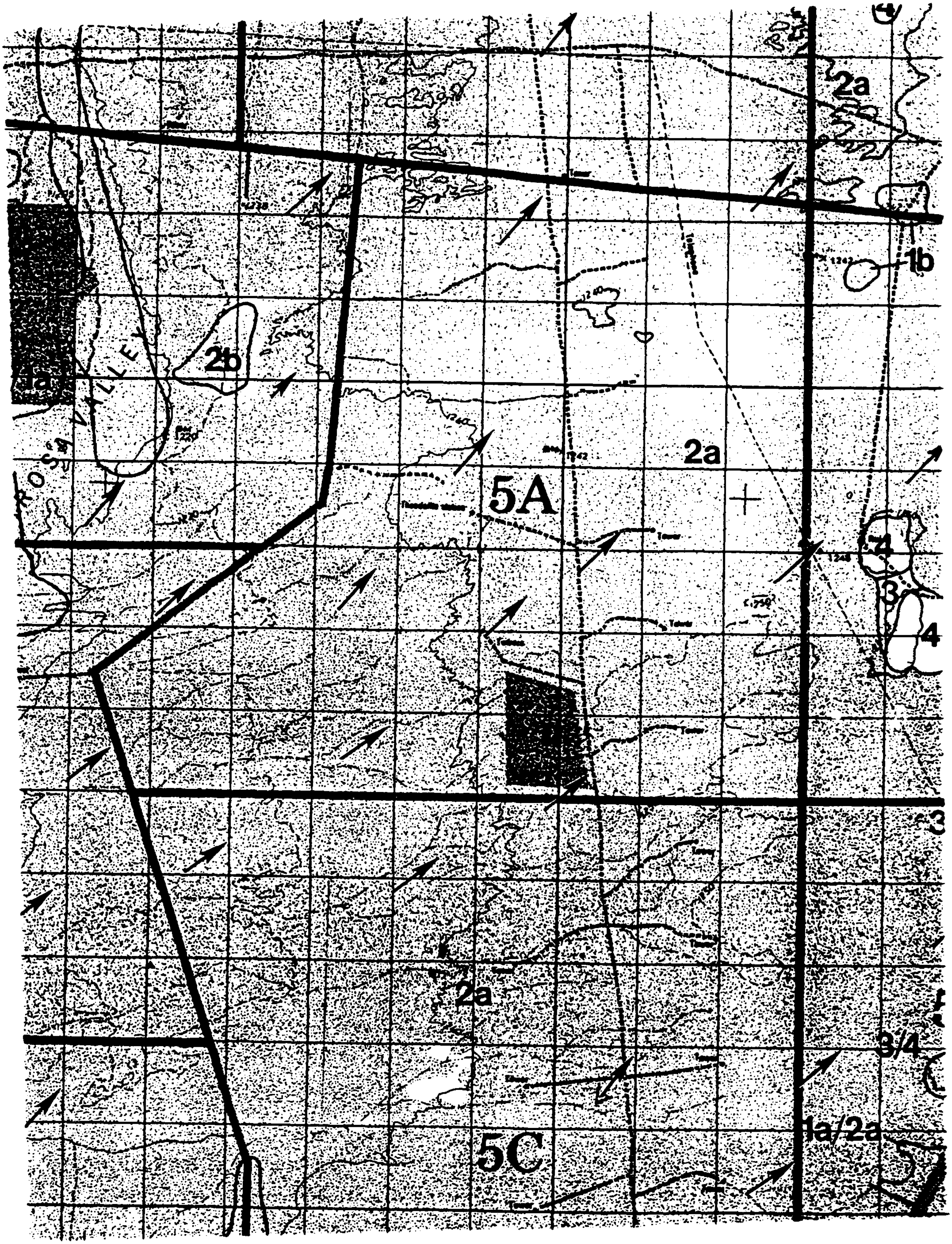

GLOBE
S. DONA ANA-OROGRANDE COMPLEX
DONA ANA COUNTY
OTERO COUNTY
1b
2b
4
4A
2a
4/3
2a
4
2b
4B
2b/3
2a
2a/1a
SCOTT TANK
2b/1b
1a
3
2a
4C
2b/1b
2b
2a
2b
4
4
73
72
71
70
69
68
67
66
65
64
63
61
Black Hills

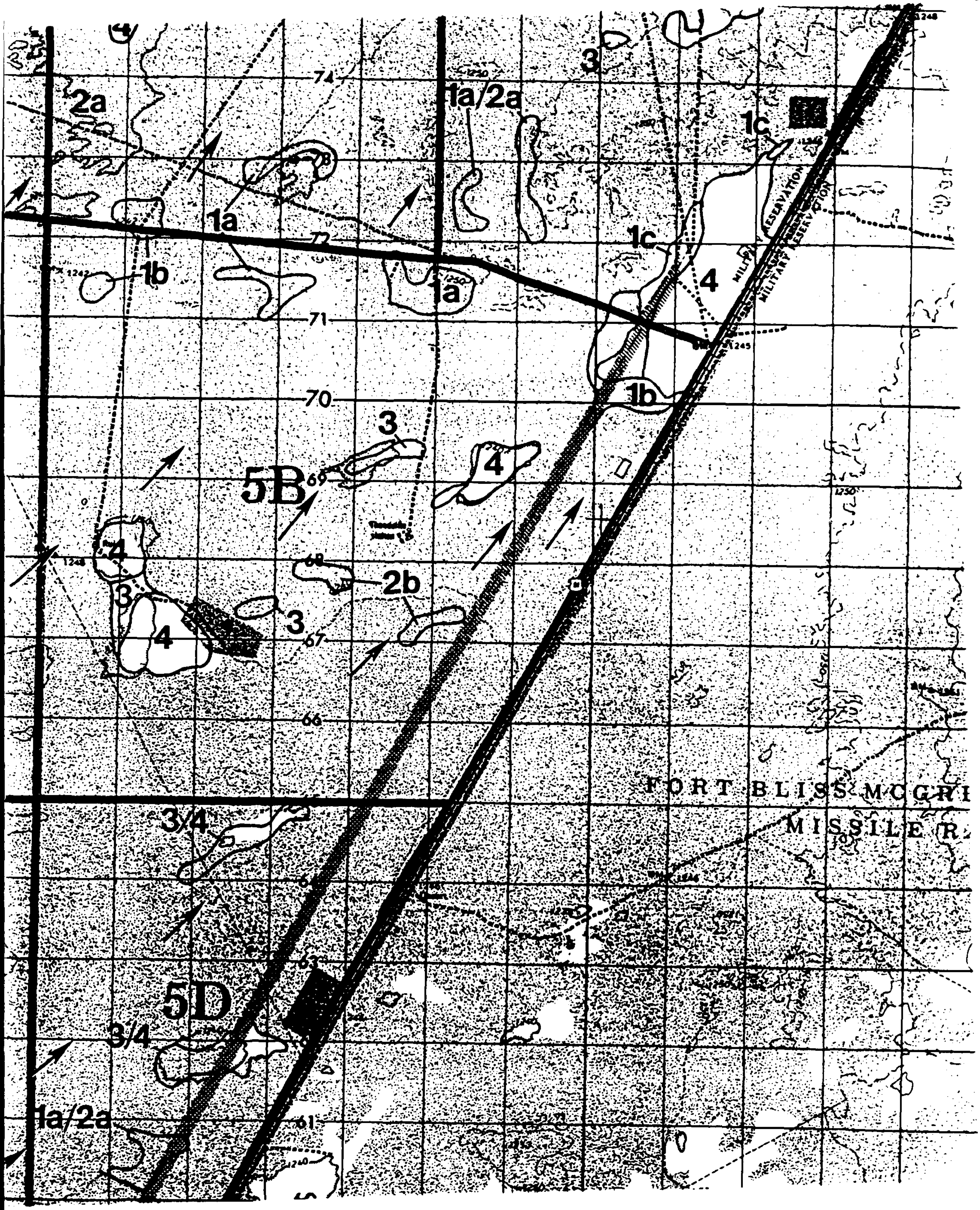


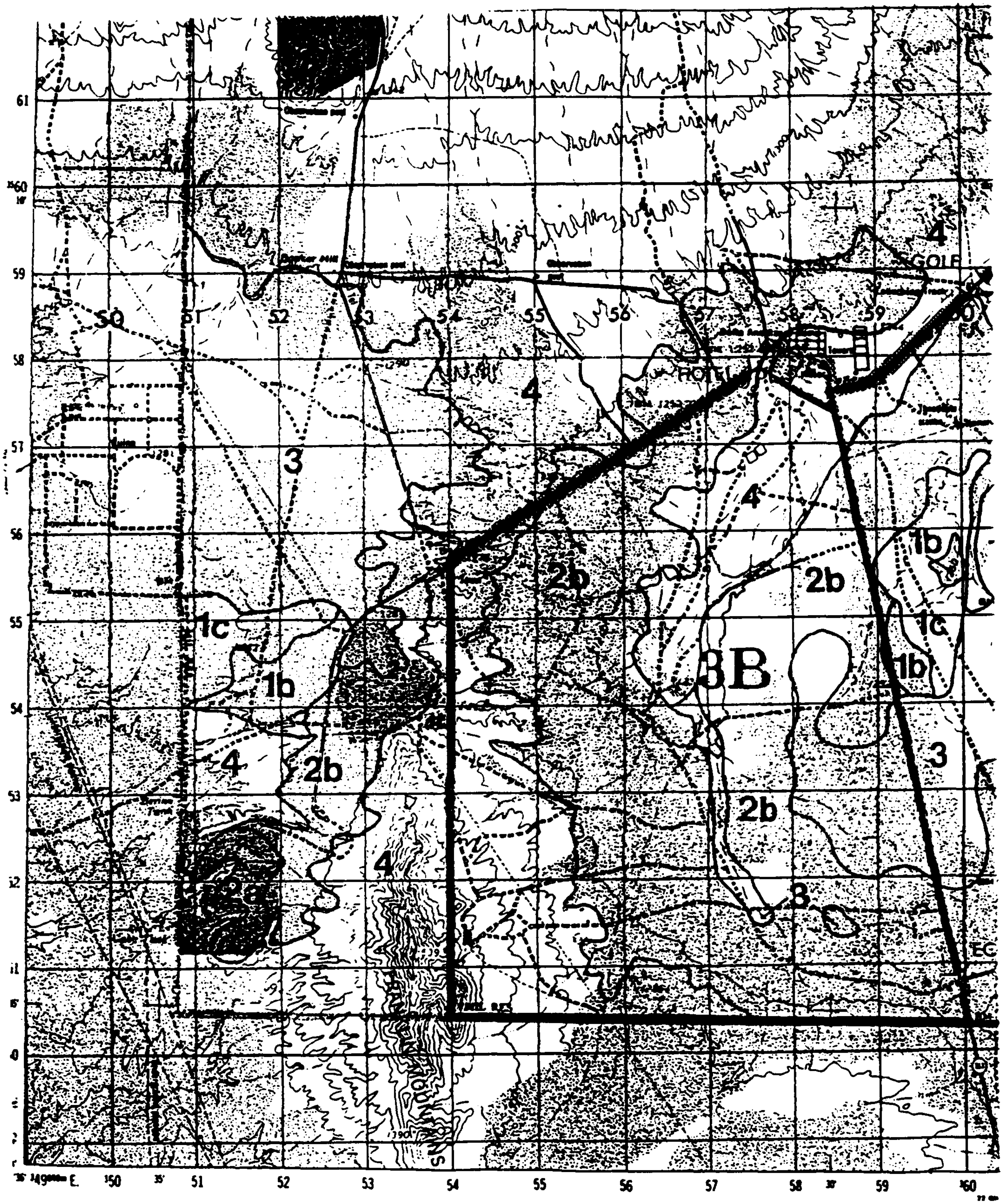
ANDE COMPLEX
2b
1b
2b/1b
DOÑA ANA COUNTY
OTERO COUNTY
1b
4A
4
2b
2a/1a
2a
2b
4/3
LA ROSA VALLEY
2b
2a
2a
2b
COE LAKE
2a
4
2b
2b
2b
4B
2a
2b/3
a
2a
SCOTT TANK
2a/1a
2b/1b
1a
3
2a
4C
67
68
69
70
71
72
73
74
75



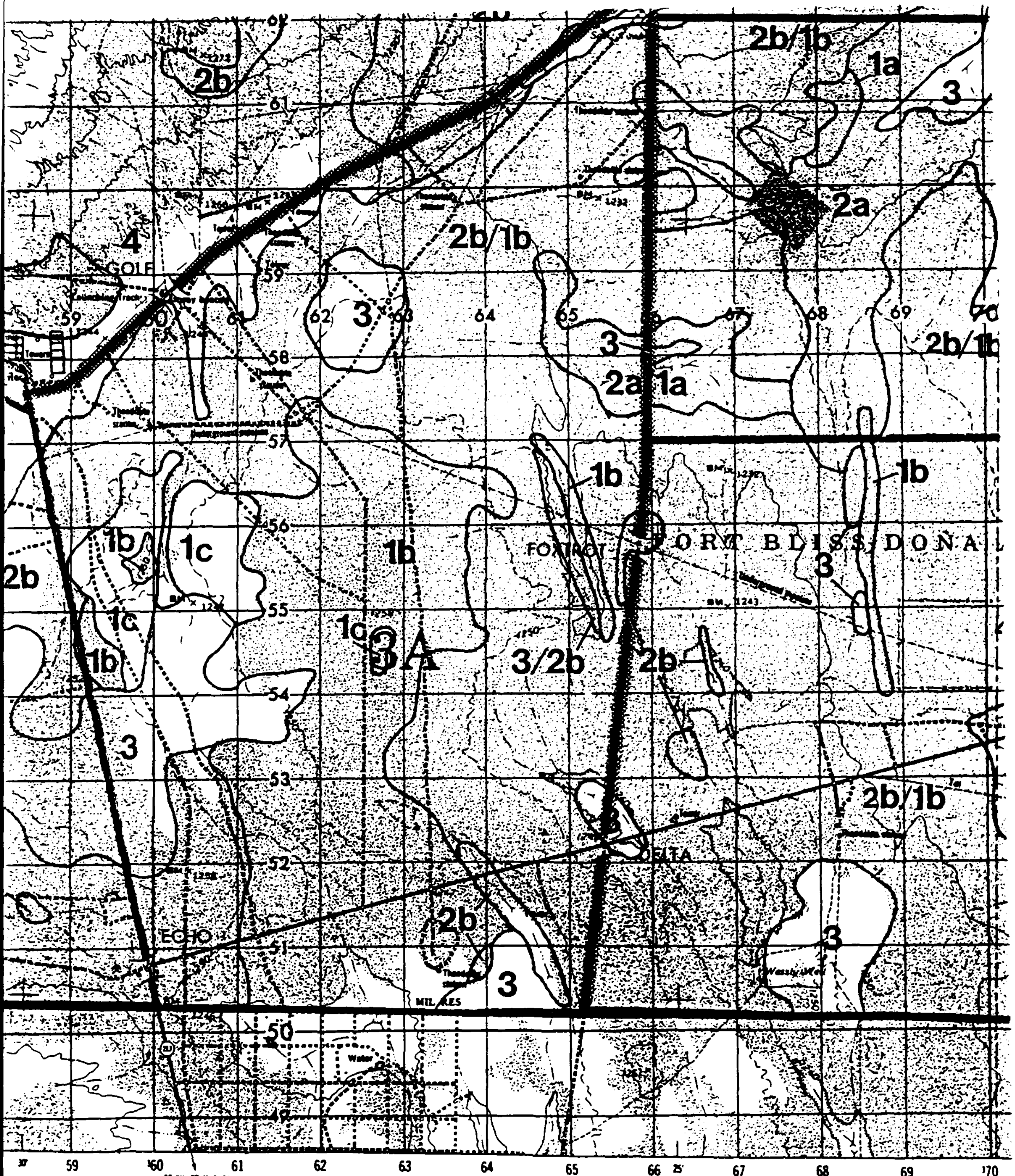
1a
1b
2b
VALLEY
2a
5A
5B
4
3
3
4
3/4
5D
3/4
2a
1a/2a
5C

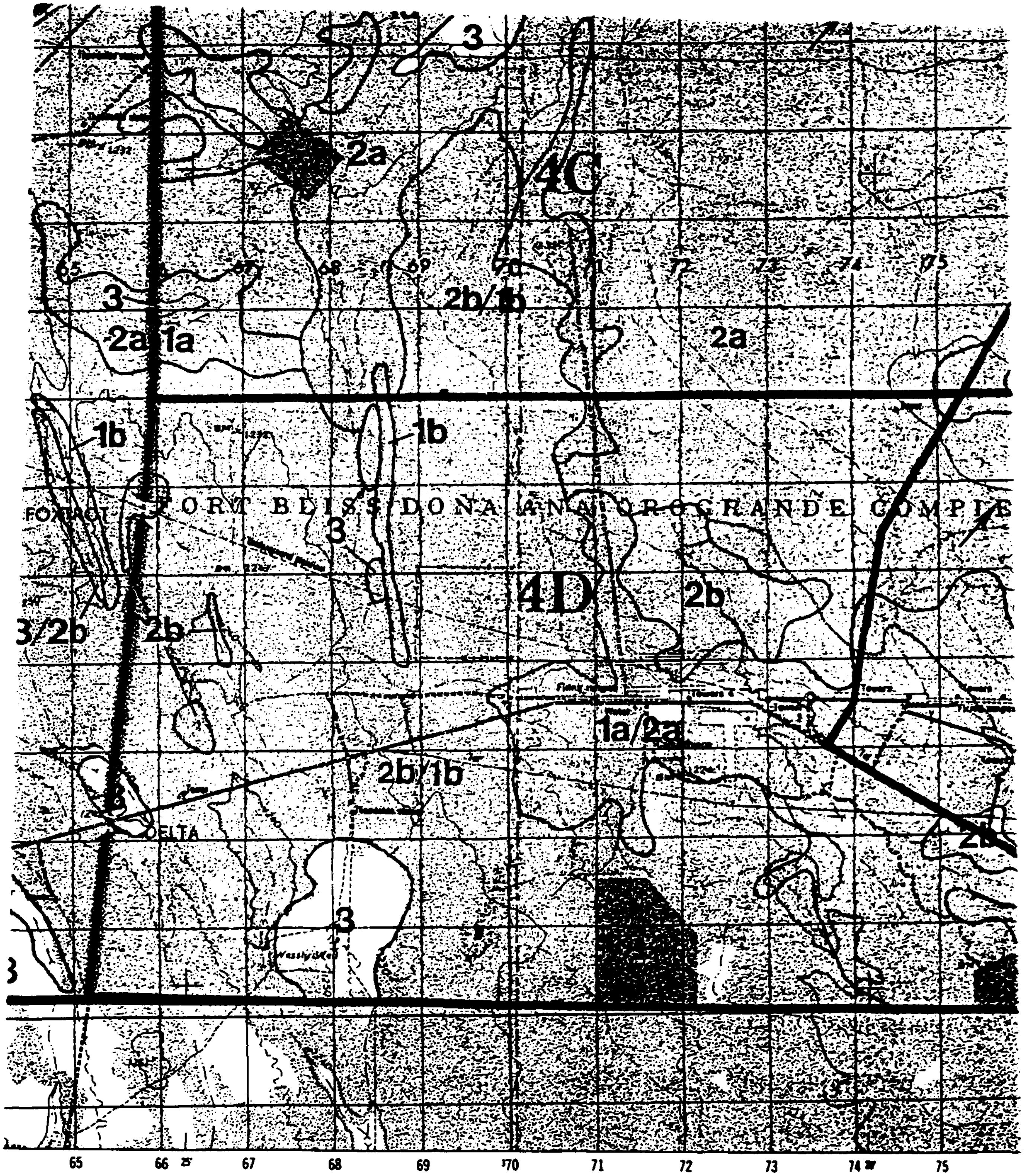

2a
1b
2b
ROSA VALLEY
1a
2a
5A
4
3
4
3
2a
3/4
1a/2a
5C


2a
1a/2a
3
1c
1a
1c
1b
1a
4
MILITARY RESERVATION
1b
3
4
5B
4
2b
3
4
3
3/4
5D
3/4
1a/2a
FORT BLISS
74
72
71
70
69
68
67
66
61

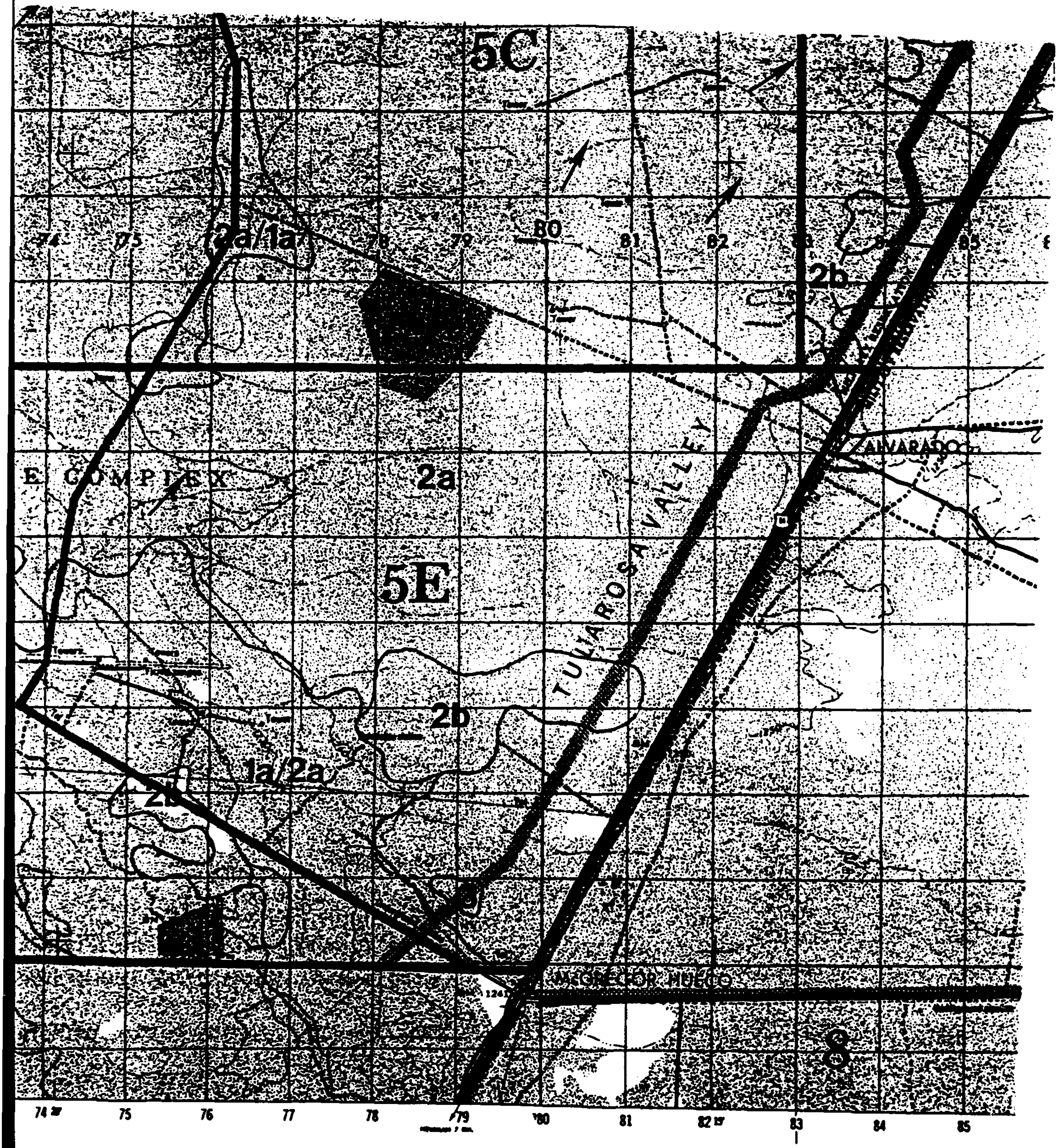


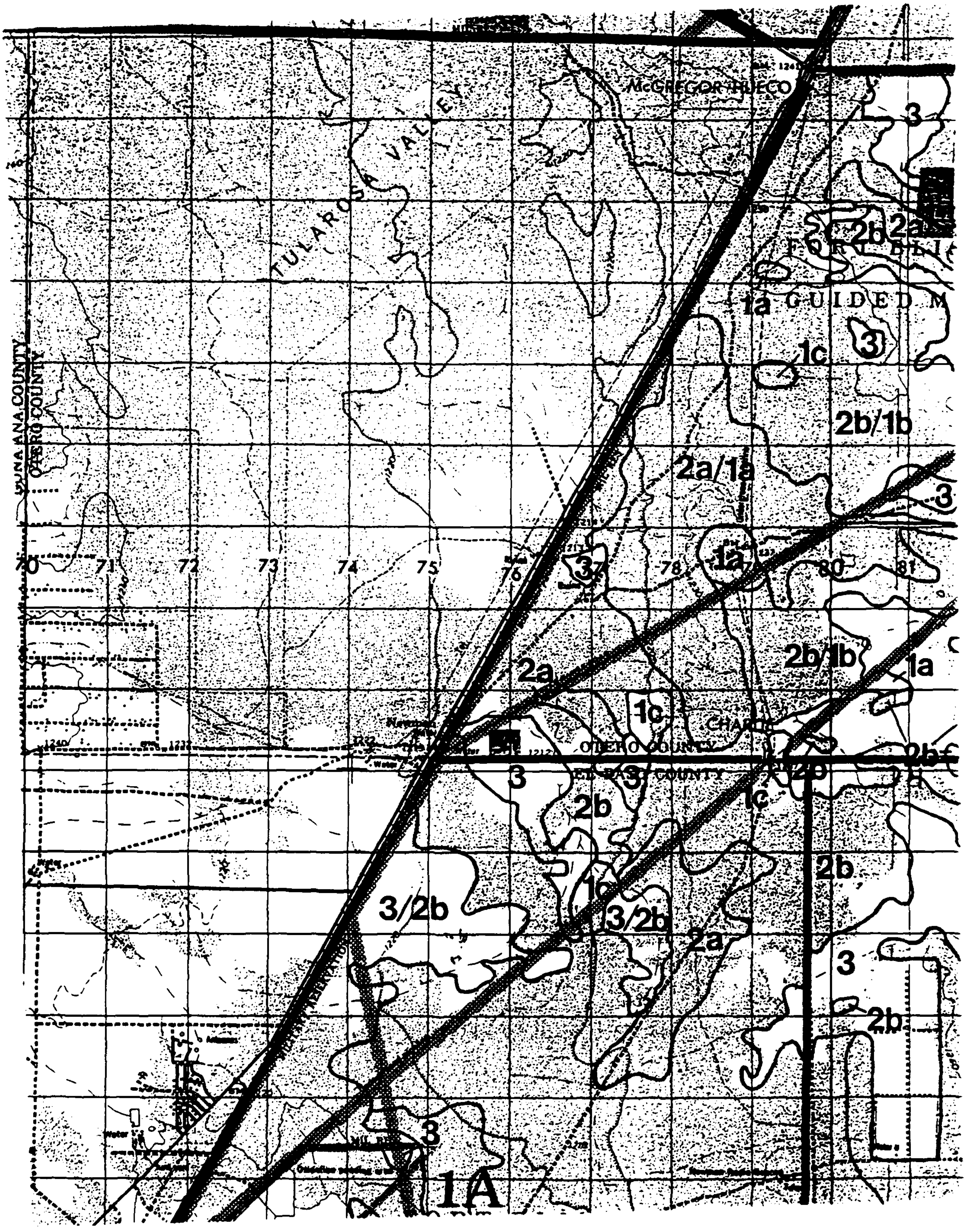
61
59
58
57
56
55
54
53
50
51
52
53
54
55
56
57
58
59
60
4
GOLF
4
3
4
1b
2b
2b
1c
3B
1c
1b
1b
3
4
2b
2b
4
3
149000m E.
150


2b
2b/1b
1a
3
2a
4
GOLF
2b/1b
3
3
2a 1a
1b
1b
1c
1b
2b
1c
1b
1c
1b
3/2b
2b
FOXTROT
FORT BLISS DOÑA
3
3
2b/1b
DELTA
2b
ECHO
3
MILLES
3
Water
59
60
61
62
63
64
65
66
67
68
69
70

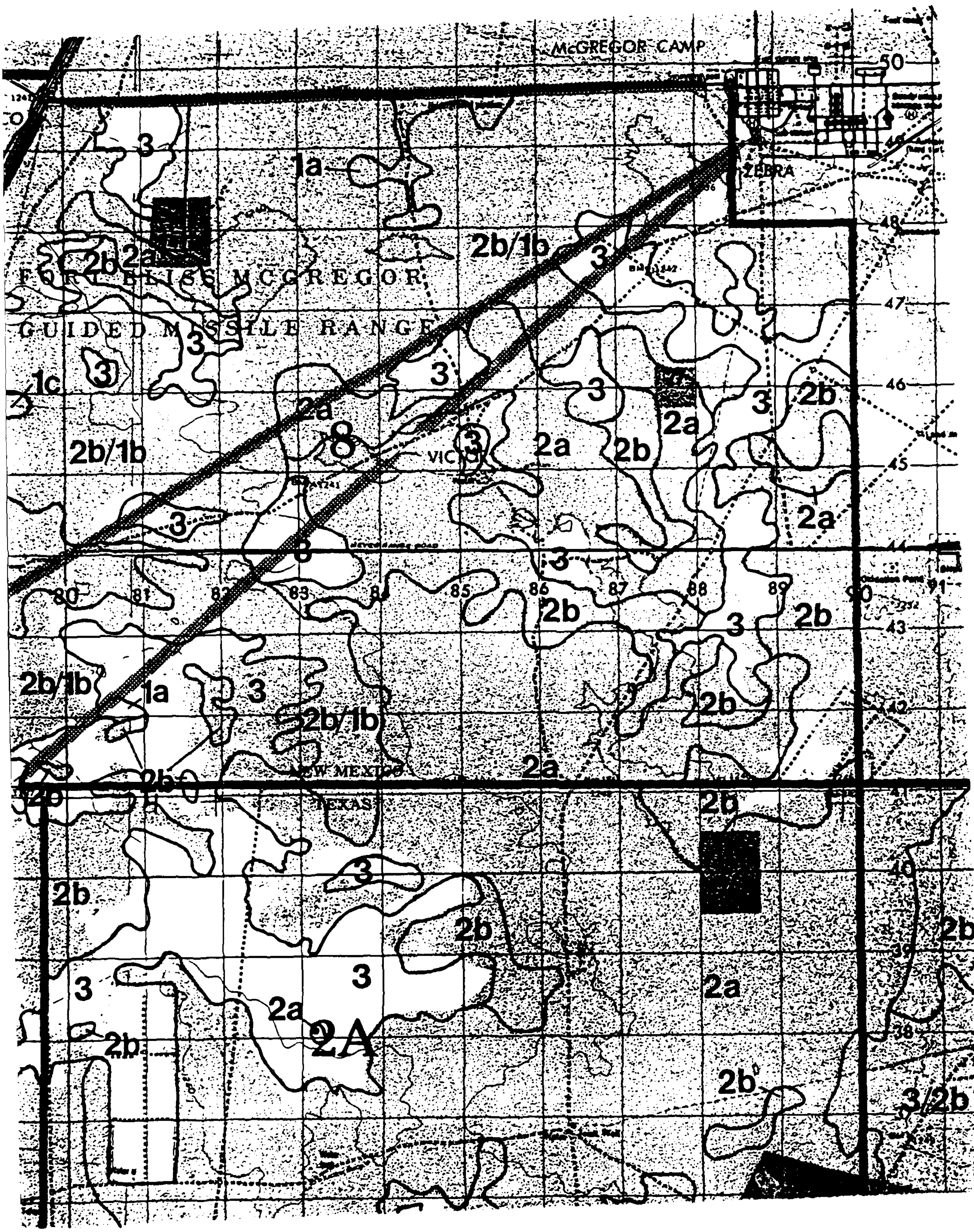


3
2a
4C
2b/1b
2a/1a
2a
1b
1b
FORT BLISS DONA ANA OROGRANDE COMPLE
3
4D
2b
3/2b
2b
1a/2a
2b/1b
DELTA
3
65
66
67
68
69
70
71
72
73
74
75

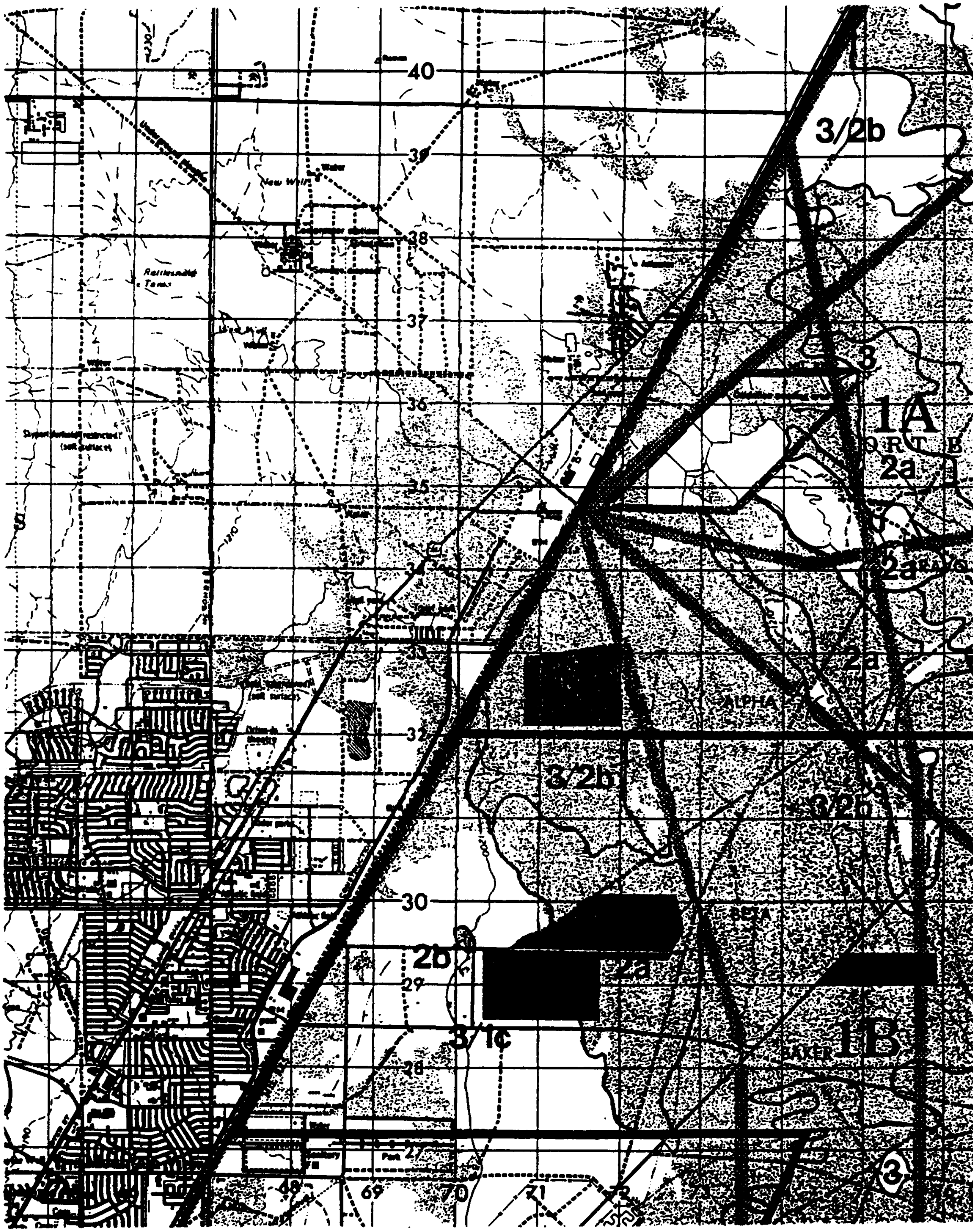

5C
2a/1a
2b
E COMPLEX
2a
5E
TULAROSA VALLEY
ALVARADO
2b
1a/2a
8
74
75
76
77
78
79
80
81
82
83
84
85



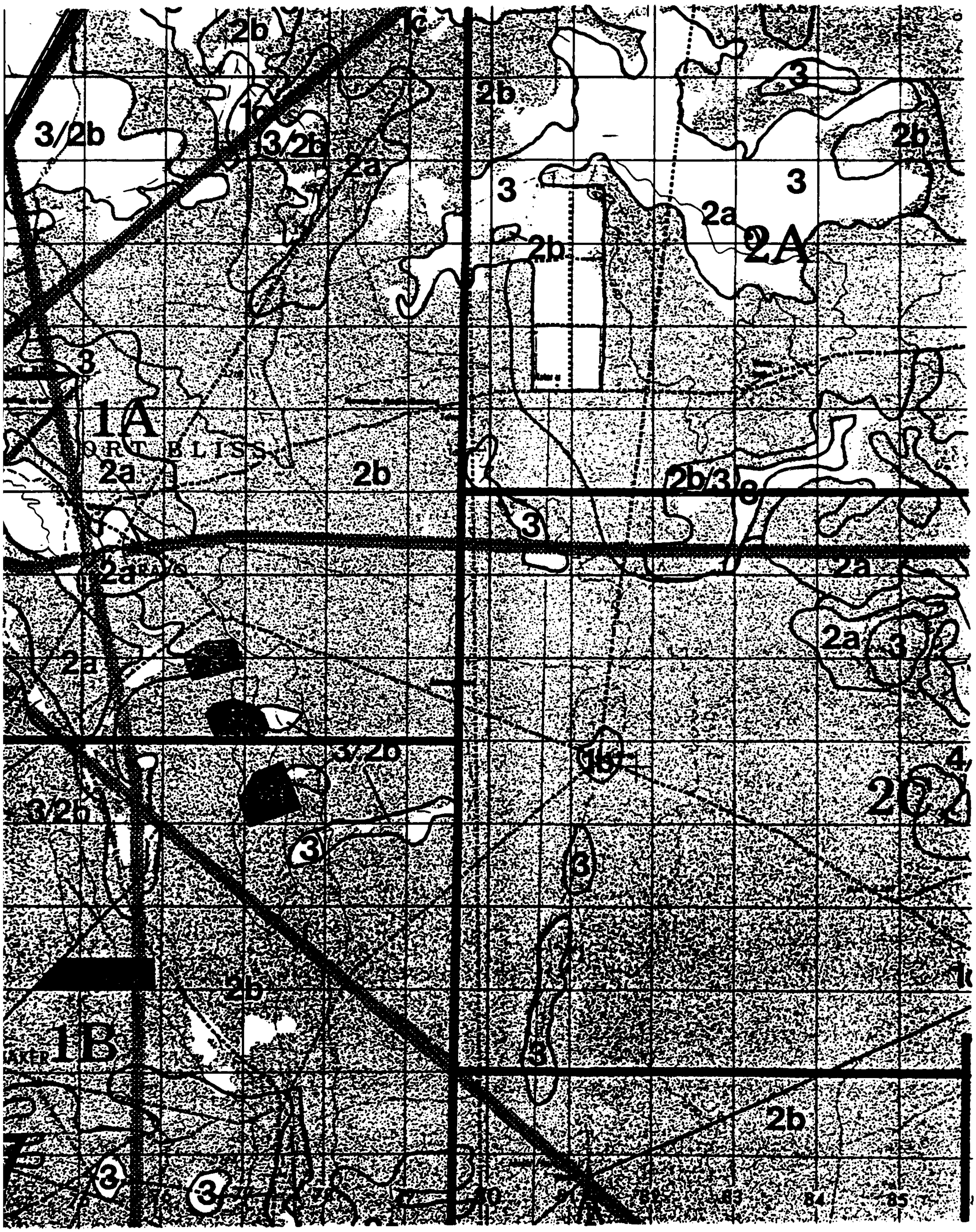
McGREGOR-HUECO
3
2b
2a
1a
GUIDED
1c
3
2b/1b
2a/1a
3
OTERO COUNTY
70
71
72
73
74
75
76
78
80
81
3
1a
2b/1b
1a
2a
1c
OTERO COUNTY
EL PASO COUNTY
3
2b
1c
2b
1c
3/2b
3/2b
2a
3
2b
3
1A


McGREGOR CAMP
ZEBRA
FORT BLISS McGREGOR
GUIDED MISSILE RANGE
NEW MEXICO
TEXAS
1a
1c
2a
2b
2b/1b
3
3/2b
2A

1



40
39
38
37
36
35
33
32
30
29
28
27
3/2b
1A
2a
2a
2a
3/2b
3/2b
ALPHA
2b
2a
3/1c
1B
68
69
70
71
3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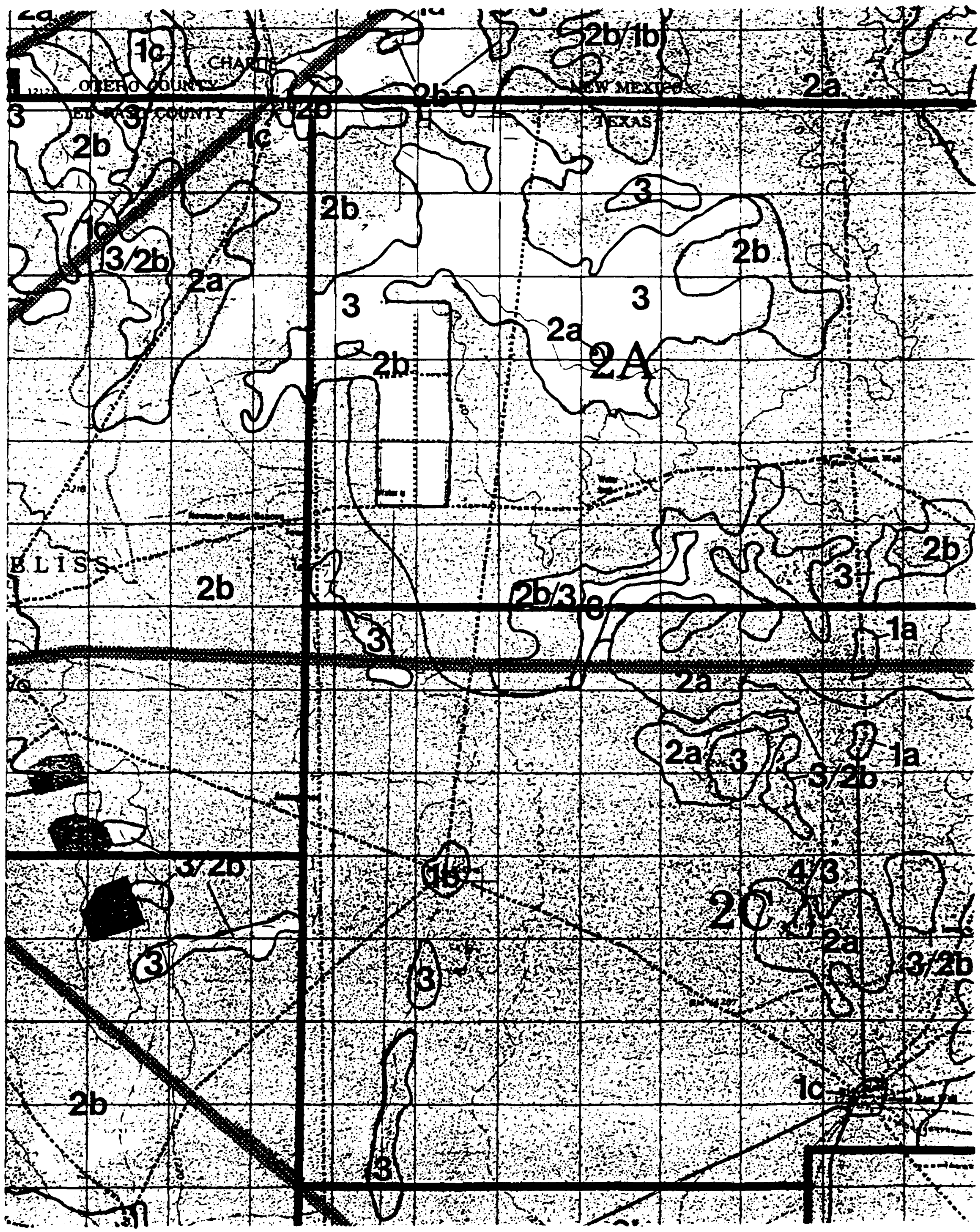

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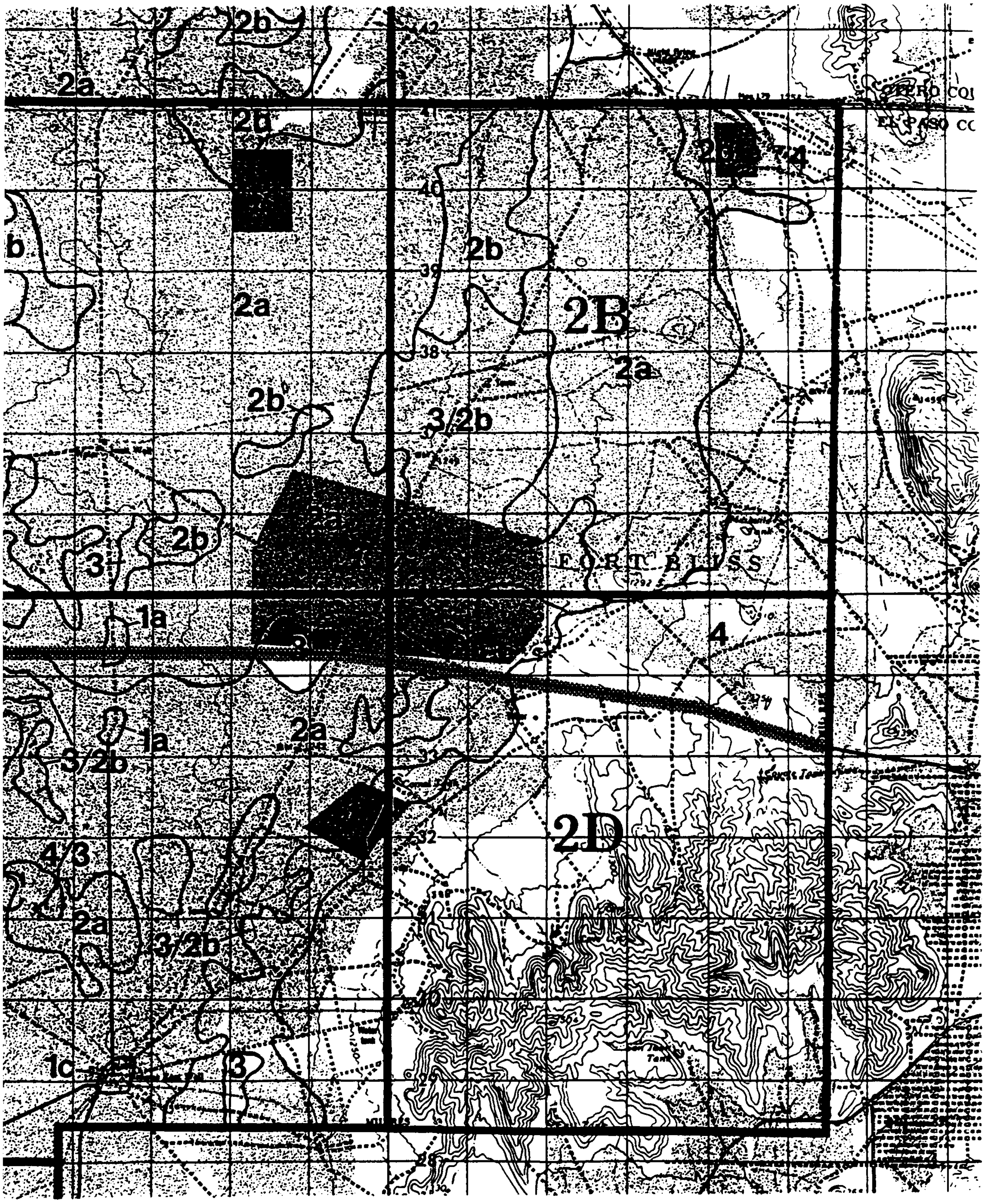
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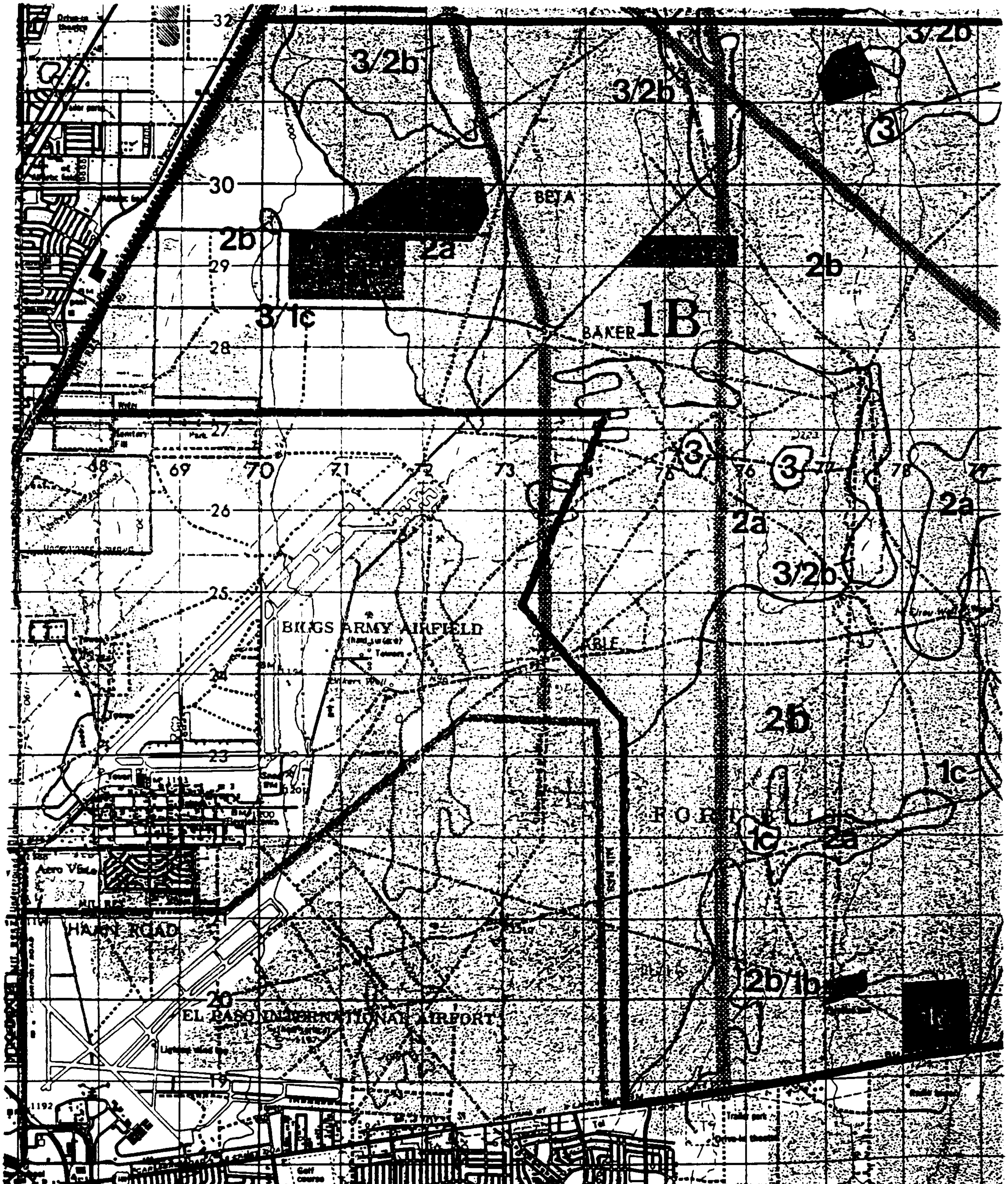

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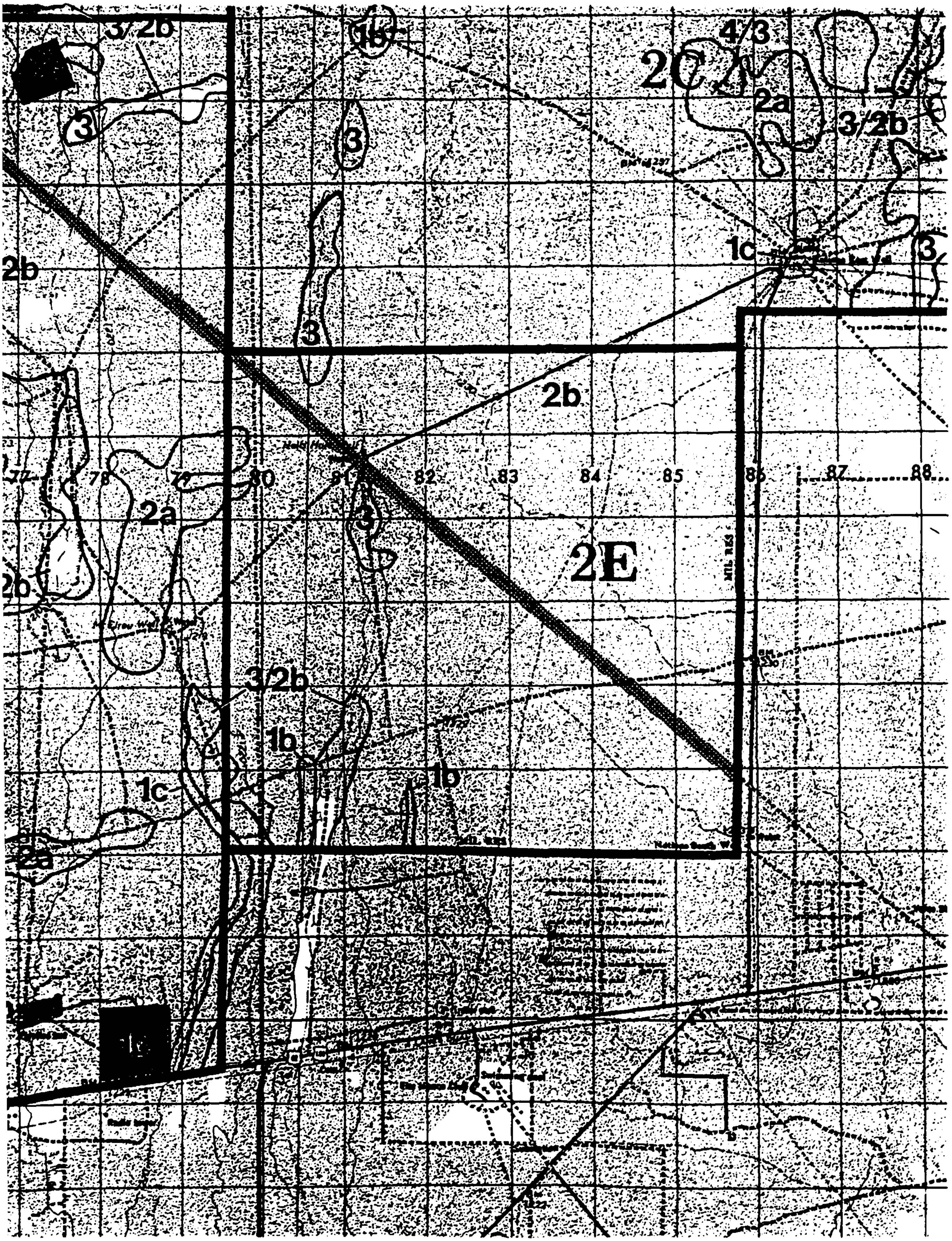
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Chapter V

GEOMORPHIC INVESTIGATION OF A POSSIBLE PALEOLAKE ON McGREGOR RANGE

By Sa'eb A. Khresat

Introduction

Archeological and paleoenvironmental studies of a cave in the Hueco Mountains east of Orogrande, New Mexico, have revealed the possibility of paleo-Indian existence before 12,000 B.P. An intermontane basin west of the paleo-Indian site contains eolian, fan-piedmont, and possibly lacustrine deposits that could contain information relevant to archeological studies. The purpose of this study is to investigate the soils developed in the intermontane basin deposits in order to reconstruct the geomorphic evolution of the area. The results show the basin was not occupied by a late Pleistocene paleolake as suspected. Alluvial plain deposits were the major deposits in the basin. Haplargids were found on older surfaces while Torripsamments were found on younger and unstable surfaces.

The first question addressed in this study was: Was there a lake in this basin in the late Pleistocene? If not, what is the basin's geomorphic history? This information is very important for archaeologists, geomorphologists, and land-resources planners. The second part of this study called for the establishment of a relationship between the geomorphic surfaces of the basin and soil genesis. Such a relationship is a key to understanding soil behavior; consequently allowing for better utilization and proper planning.

This study is based on observations of particular landforms in the intermontane basin that may help determine the processes and methods that contributed to the formation of these features. By establishing a relationship between geomorphic surfaces and the degree of soil development in the study area, the region's geomorphic history will be deduced and the soil development patterns can be interpreted and comprehended.

Three hypotheses were formulated to study the area's geomorphic evolution.

- Hypothesis A: The basin was occupied by a lake during the late Pleistocene.
- Hypothesis B: The basin was flooded and once was a marshland.
- Hypothesis C: The basin represents an alluvial plain.

To test the hypotheses the following objectives were set.

- Map the basin's geomorphic surface.
- Examine soil development stages.
- Examine the basin's depositional processes.
- Examine pollen chronology.
- Classify soil according to the USDA system.

By studying the pedogenesis and associated soil properties, it is possible to interpret soils in terms of the climate, vegetation, and moisture conditions under which they were developed, thus enabling us to reconstruct the paleoclimate of the area.

The purpose of this study was to investigate the soils developed in intermontane basin deposits in order to reconstruct the geomorphic evolution of the area. Gile and Grossman studied the soils and the geomorphic surfaces of the Las Cruces area and provided information about the geomorphic surface evolution, soil formation, and paleoclimate reconstruction (Gile and Grossman 1979).

The Quaternary history of southern New Mexico has been characterized by continued tectonic deformation and volcanic activity (Hawley 1975). On middle Pleistocene-age surfaces, the soil shows prominent clay illuviation and, in some places, secondary calcium carbonate accumulation. This indicates the surfaces were stable for enough time to allow the illuviation processes to take place (Gile and Grossman 1979; Gile et al. 1981). Preliminary studies and examination of field and satellite data suggest the possibility of a paleolake in a basin northeast of Orogrande. This site is a nearly closed basin in a semiarid area that receives water from the surrounding mountains. The study area's major geomorphic features include an intermontane basin and piedmont slopes. Eolian deposits also are widespread in the basin floor (Hawley 1992).

Alluvial deposits are the main component of the basin fill, and merging or coalescent fan piedmont and basin floor alluvial plains form broad constructional surfaces of middle and late Quaternary age (Hawley 1992). Since the early Pleistocene the dominant geomorphic processes in this area were eolian activity and playa deposition (Blair et al. 1990).

Materials and Methods

Location

The study area, located northeast of Orogrande in the Tularosa Basin of southern New Mexico (see Figure V-1), is in the Mexican Highland section of the Basin and Range Province. It is bounded by the Sacramento Mountains on the east and northeast and the Jarilla Mountains on the west. The Jarilla Mountains consist of upper Paleozoic sedimentary beds intruded by a series of intermediate igneous rocks (Schmidt et al. 1964).

The site elevation is about 1,247 m above sea level. The lowest point in the area is 1,239 m above sea level. Lake Otero was located northwest of the study area and occupied an area of 460 km^2 and had a maximum elevation of 1,204 m (Hawley 1992). Alluvial deposits may contain information valuable to reconstruction of the area's geomorphic history.

Climate

The basin climate is typical of many of the more arid parts of the southwestern United States and northern Mexico (USDA 1981). Temperatures are lowest in December and January and highest during June, July, and August, when they surpass 38°C. Annual precipitation in the Tularosa Basin averages less than 250 mm annually. Rain falls primarily during the summer, generally in the form of short, high-intensity, isolated thunderstorms that can cause flash flooding (USDA 1981). Relative humidity ranges from 40 to 60 percent (Medellin-Leal 1982). Winds generally blow from the west in the spring and dust storms are common in the area throughout the season. The soil surface usually is dry during the winter and spring, when wind speeds reach their maximum (Blair et al. 1990).

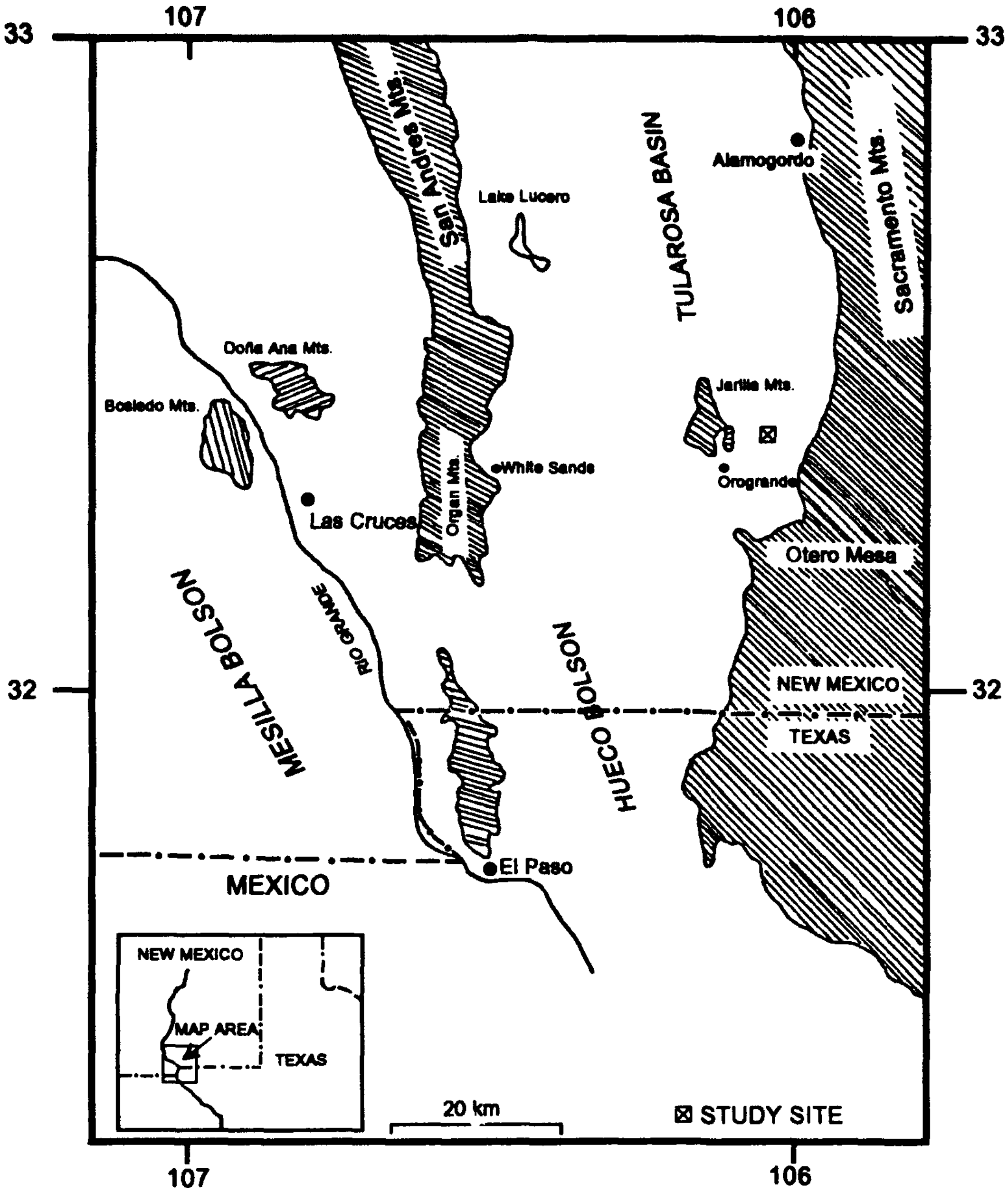


Figure V-1. Study Area

Pedologic evidence from the nearby Desert Project showed clay accumulation in the deeper soil horizons. This indication of more available moisture for leaching suggests a wetter past climate than the prevailing one (Gile and Grossman 1979; Gile et al. 1981).

Vegetation

Yucca *(Yucca baccata)*, mesquite *(Prosopis juliflora)*, creosote bush *(Larrea divaricata)*, Tobosa grass *(Hilaria mutcia)*, black grama *(Bouteloua eripoda)*, burro grass *(Scleropogon brevilfolius)*, bush muhly *(Muhlenbergia porteri)*, blue gram *(Bouteloua gracilis)*, snakeweed *(Gutierrezia sarothrae)*, sand sage *(Artemesia filifolia)*, and drop seed *(Sporobolus cryptandrus)* are the primary flora of the study area (USDA 1981).

Geology

Sedimentary and igneous rock are exposed on both sides of the Tularosa Basin in the San Andres and Sacramento mountains. Sediments fill the Tularosa Basin to a depth of more than 1,000 m. The sides of the basin are characterized by steep alluvial fans and piedmont slopes (Noyes et al. 1987).

Basin deposits, Quaternary sedimentary in nature, are of alluvial, dune, and playa origin, among others (Noyes et al. 1987). The deposits overlie Permian sedimentary rocks and Precambrian rocks (see Figure V-2).

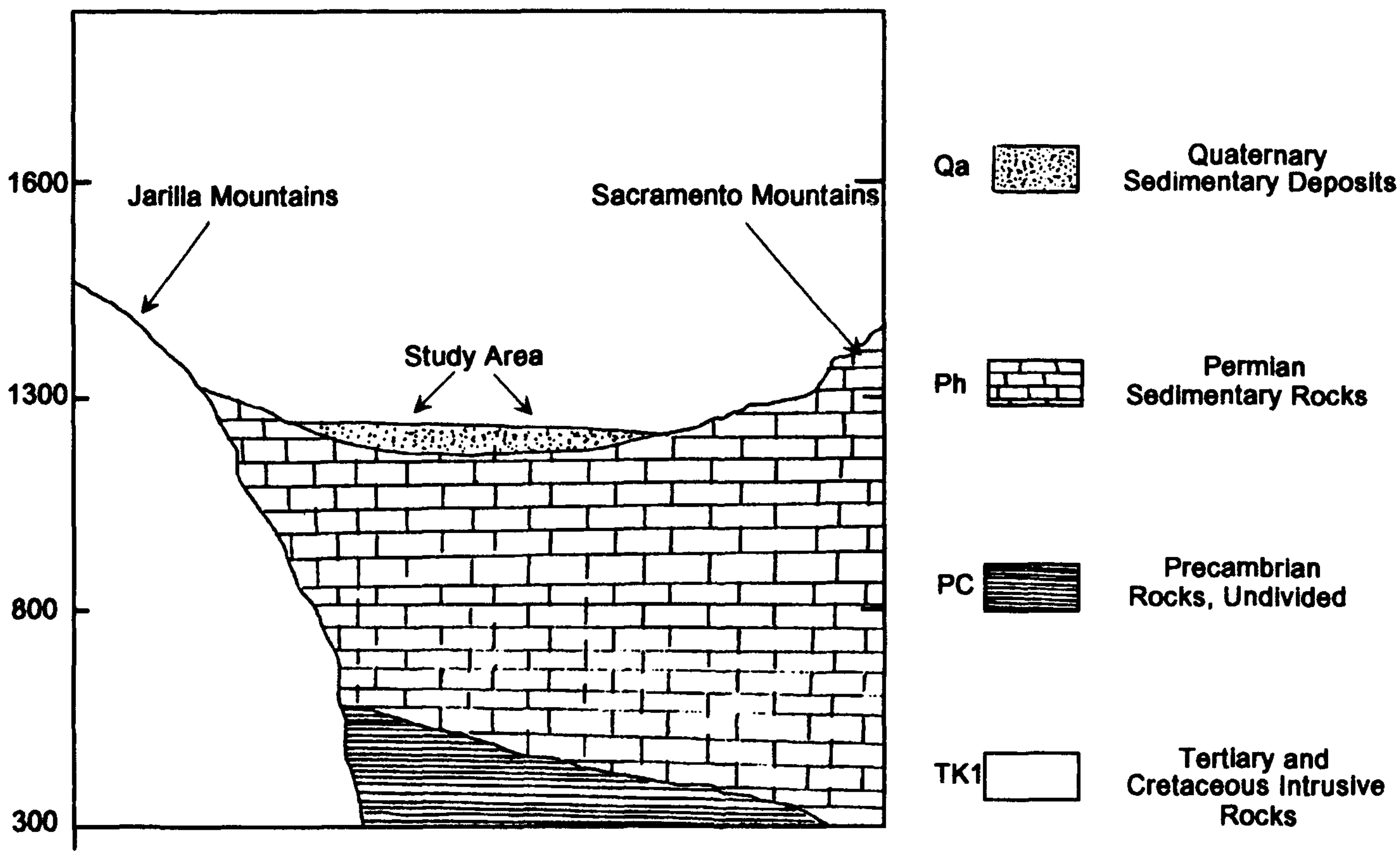


Figure V-2. Geological Cross Section of Study Site (after Noyes et al. 1987)

Site Selection

The first site was chosen on a short, steep slope that resembled a terrace. The second site was chosen at the second topographic break. The third and fourth sites were in the lowest spot of the study area.

Laboratory Analysis

Sample Preparation

Samples were taken from backhoe trenches after soil profiles were described according to U.S.. Soil Survey nomenclature (Soil Survey Staff 1981). Samples were air dried, passed through a 2-mm sieve, and kept in containers for analysis. The soil portion greater than 2 mm was kept for future analysis. Natural, undisturbed samples were saved for particle size analysis and thin sections.

Particle Size Distribution

Particle size distribution was determined using the hydrometer method described by Gee and Bauder 1986. Samples were placed in 0.5 M hydrochloric acid to remove the carbonates. Organic matter then was removed by heating the sample with 31 percent hydrogen peroxide. Dispersion was accomplished by adding 100 ml of sodium hexametaphosphate. Sand fractions were separated by standard sieves to determine the percentages of very coarse, coarse, medium, fine, and very fine sand.

Particle size was studied to determine lithological discontinuity and stratification. This was used to interpret the area's depositional processes.

Organic Matter

Organic matter content was determined using the potassium dichromate method (Walkley 1946). This analysis brought forth any accumulation of organic matter, especially in the subsurface horizons, that could be related to reduced conditions.

Soil pH and Soluble Salts

Soil pH and electrical conductivity (soluble salts) were studied through the 1:1 soil-to-water ratio method described by Rhoades (1982). The soluble salts were used to study the effectiveness of leaching in the soil profile.

Carbonates

Carbonates were neutralized using the acid neutralization method (Richards 1954) with excess 0.5 N HCL and back titrated with 0.5 N NaOH.

Carbonate content is important in identifying calcic horizons. It interferes with argillic horizon formation and consequently changes soil morphology and classification. Carbonate content also was used as an age parameter.

Mineralogical Studies

The Jackson method (1973) was utilized to find X-ray diffraction patterns. The samples were ground to a fine powder with alcohol and then spread evenly over the surface of glass slides. X-ray diffraction patterns were obtained using a Rigaku instrument operated at 40 KV and 30 ma, using a Cuk radiation. Powder samples were examined from 20-45. Thin sections were prepared in the search for lithological discontinuity and any fossil presence.

Pollen Analysis

A paleontologist studied the soil samples to determine the pollen record. The record, in turn, was an aid in examining the marshland hypothesis and was used to shed more light on paleovegetation and its chronology. Paleovegetation determination provides a good indication of paleotemperatures (Reeves 1968).

Geomorphic Surface Mapping

The study area's geomorphic surfaces were mapped by satellite imaging and field reconnaissance. The mapping helped to unravel the area's geomorphic history and to establish a relationship between the geomorphic features and soil classification.

Profile Descriptions

Profile 1

Classification: Sandy, mixed, thermic, typic Haplargids
Location: (*DF 032835*). SE 1/4, SW 1/4, Sec. 16, T 22S, R 9E
Elevation: 1,240 m (4,090 feet)
Vegetation: Sand sage (*Artemesia filifolia*) and yucca (*Yucca baccata*)
Parent Material: Alluvium limestone
Geomorphic Surface: Jornada II

Soil Description

A	0-30	7.5YR 6/4-7.5YR 5/3, sandy clay loam, medium platy, slightly hard, friable, slightly sticky, slightly plastic, slightly effervescent, many medium and fine roots, no gravels, very few very fine pores, clear boundary. (sand, silt layering)
C1	30-115	5YR 6/6, sand, structureless, soft, very friable, nonsticky, nonplastic, no effervescence, more than 50 percent coarse roots, no gravels, gradual boundary
C2	115-150	7.5YR 5/4, loamy sand, structureless, soft, very friable, nonsticky, nonplastic, very few coarse roots, very few small gravels, no effervescence, clear boundary

Ck	150-185	7.5YR 5/4, loamy sand, structureless, slightly hard, friable, nonsticky, nonplastic, strong effervescence, few fine roots, very few very fine pores, smooth boundary
Bk	185-230	7.5YR 8/2-7.5YR 6/3, sandy clay loam, moderate angular blocky, hard, friable, slightly sticky, slightly plastic, strong effervescence, no roots, few fine pores, gradual boundary
Btk	230-250	7.5YR 8/2-7.5YR 5/4, sandy clay loam, strong angular blocky, hard, very firm, slightly sticky, few fine pores, very few fine roots

Profile 2

Classification: Coarse loamy, mixed, thermic, Typic Paleargid
Location: (*DF 038834*). NE 1/4, NW 1/4, Sec. 21, T22S, R9E
Elevation: 1,237 m (4,082 feet)
Vegetation: Sand sage (*Artemesia filifolia*) and mesquite (*Prosopis juliflora*)
Parent Material: Alluvium
Geomorphic Surface: Isaacks' Ranch

Soil Description:

A	0-30	7.5YR 6/4, loamy sand, platy-granular, slightly hard, friable, nonsticky, nonplastic, many fine and medium roots, few fine pores, gradual boundary
Bk1	30-120	7.5YR 5/4, sandy loam, moderate subangular blocky, slightly hard, friable, slightly sticky, slightly plastic, few medium roots, few rounded gravels, clear boundary
Btk	120-200	7.5YR 6/4, sandy clay, moderate angular to subangular blocky, hard, firm, sticky, plastic, cortovina present, gradual boundary
Ck1	200-210	7.5YR 7/3, sandy loam, structureless, slightly hard, friable, slightly sticky, slightly plastic, strong effervescence, clear boundary
Ck2	210-220	5YR 8/2, structureless, hard, firm, slightly sticky, slightly plastic, strong effervescence, clear boundary
Ck3	220-250	7.5YR 6/4, sandy loam, structureless, slightly hard, friable, slightly sticky, slightly plastic, strong effervescence, clear boundary
C1	250-260	10YR 6/3, sandy loam, structureless, loose, very friable, nonsticky, nonplastic, well-sorted sand Mica

Profile 3

Classification: Sandy, mixed, thermic, Typic Torripsamments
Location: (*DF 043833*). NW 1/4, NW 1/4, Sec. 22, T22S, R9E
Elevation: 1,238 m (4,086 feet)
Vegetation: Sand sage (*Artemesia filifolia*) and mesquite (*Prosopis juliflora*)
Parent Material: Alluvium
Geomorphic Surface: Organ

Soil Description

A	0-35	5YR 5/4, loamy sand, granular, loose, friable, slightly sticky, many medium and coarse roots, few fine pores, gradual boundary
C	35-100	5YR 6/4, sand, structureless, loose, very friable, nonsticky, fine roots, no effervescence, gradual boundary

Ck1	100-290	5YR 6/4, sand, structureless, loose, very friable, nonsticky, no roots, clear boundary
Ck2	290-312	5YR 8/1, sandy loam, structureless, hard, very firm, sticky, no roots, clear boundary
Ck3	312-340	5YR 8/1, sand, structureless, hard, very firm, sticky

Results and Discussion

Paleolake Hypothesis

Preliminary field examination of the study area suggested the presence of a paleolake that could have influenced the paleo-Indians in the nearby Pendejo Cave in the Hueco Mountains east of the study area. Two topographic breaks were thought to be relict shorelines of a late Pleistocene lake. After examining the stratigraphic record of the studied sites, no evidence of interbedded clay, varves, ripple marks, parting lineations, graded bedding, mudcracks, fossil presence, or evaporite minerals were found. These features usually are associated with lacustrine or playa sediments (Boggs 1987). The thickness of the deposits is very useful in differentiating basin floor sediments from lacustrine sediments, where lacustrine sediments are more laminated and stratified than the thick basin floor sediments (Boggs 1987). The basin deposits were not laminated or stratified, and appears not to be of lacustrine origin.

Also, the geomorphic features of the area do not exhibit any evidence of lake shorelines, wave cut benches, gravel beach ridges, terraces, spits, or bars. These features are common in pluvial lakes areas in the Range and Basin province of the southwestern United States (Morrison 1991).

Lake Otero's maximum elevation (1,204 m) and the study area's minimum (1,247 m) rule out the possibility that the site might have been a finger lake of Lake Otero because of the elevation differences. Another piece of topographic evidence is the fact that the basin is open towards the south and is higher in elevation than the El Paso area. Therefore, if a lake was formed in the study site it should have extended to El Paso and, if this have had happened, it would have been documented by the numerous El Paso area geological studies. This difference appears to be the result of a fault west and southwest of the Jarilla Mountains (Seager 1980).

This evidence indicates the site was not occupied by a paleolake, as we previously thought, and the topographic breaks are not relict shorelines. They probably are down-dropped fault lines similar to ones shown on the geological map of northeast El Paso (Seager et al. 1987).

Marshland Hypothesis

Organic matter was studied to determine any pattern of change and reduced conditions that might be of marshlands origin. This analysis did not work well because surficial deposits in desert environments usually are thin and organic matter oxidizes rapidly after burial . The soil pH analysis, also used to find indications of reduced conditions (more acid), proved to be ineffective for the same reasons.

Mottles indicate reduced conditions (Soil Survey Staff 1975) but when the soil profiles were described, there was no indication of soil mottling (see profile description, Chapter III). Pollen analysis is the best reduced-conditions indicator but the results did not show any cattail or marshlands grass pollen. These results indicate the basin was not wetlands or marshlands in the late Pleistocene period.

Basin Floor Alluvial Deposits Hypothesis

Basin floors basically are level alluvial and lacustrine plains that occupy central basin areas (Gile et al. 1981). The particle size distribution analysis on a clay-free basis indicated there was a change in depositional processes in the studied sites (see figures V-4, V-6, and V-8). This analysis was used to assist in differentiating sediment heterogeneity and to detect lithological discontinuities. Smith and Wilding (1972) found this technique very useful in identifying lithologic discontinuity.

Perceiving lithological discontinuity is necessary in order to distinguish between geological and pedological soil properties. The discontinuities could be the result of many factors. Among these factors, especially in the arid region, are the eolian and alluvial material additions that occur during soil development.

Discontinuity can be detected in the field by color changes, structure, and texture. Sometimes it is difficult to spot the lithological discontinuity through morphological examination alone. If these variations are not clear, detailed particle size distribution and mineralogical examinations are needed to determine the discontinuity (Evans 1978).

The recalculated particle size distribution was used as a parameter to find the lithological discontinuity. The idea of a clay-free-based analysis is analogous to the removal of dye from a fabric–original material color changes can be detected. Clay is capable of being or having been moved by the process of soil formation, while sand grains are not readily translocated or reorganized by soil-forming processes (Buol et al. 1989).

Gile et al. (1981) state, "Individual landforms of intermontane basin floors include ephemeral lake plains, relict forms of ancient perennial lakes, both recent and ancient features of alluvial origin (plains, flats, and axial drainageways), and a variety of sand-dune types and other eolian forms." The depositional environments are not lacustrine or ephemeral lake plains, for the reasons mentioned earlier. The best scenario for the study site is a distal alluvial fan (Piedmont) and basin fill with a variety of sand dune types and other eolian forms.

Soil development shows a pattern of more evolvement upslope and towards the Jarilla Mountains. This appears to be the result of more stable surfaces upslope. Haplargids occur on these stable and older surfaces, while Torripsamments occur on what are considered unstable and young surfaces in the basin center.

Particle Size Distribution

Pedon 1

Particle size analysis was determined to assist in identifying stratigraphic units (see Table A1). Sand content was lowest at the soil surface and immediately increased below the A Horizon from 47.3 percent to a maximum of 89.7 percent (see Figure V-3). The high sand content below the surface horizon is attributed to strong eolian deposition, whereas the low sand on the surface is attributed to the interdune effect. Interdune flats occur commonly in the province basin floor between closely spaced large sand dunes (Pet[illegible]on 1981). Silts and clays usually are found in the interdune areas. This happens as water becomes trapped in these areas and form ponds (Boggs 1987). Silt content increases with depth below the A Horizon. This reflects sedimentation of probable Holocene age (Gile et al. 1981). During interpluvial climates, permanent lakes

were lowered significantly and evaporated as a result of the shift from a cooler and wetter environment and denser vegetative cover to a warmer and drier environment with less vegetative cover (Chadwick 1990; Dohernwend 1987; Smith et al. 1983). Silt, clay, and other salts were blown from the dried lake beds and deposited on land surfaces in the proximity of these lakes. The site is in the vicinity of Lake Lucero, which is the remaining part of Lake Otero.

Clay content also increases with depth, suggesting an illuviation process. The 3-percent clay increase for argillic horizon requirements was met at depths of 150 and 185 cm. Calcic horizon requirements were met at depths of 185 and 230 cm but these horizons are not diagnostic in soil classification because their upper boundaries are not within 100 cm of the surface (Soil Survey Staff 1975). Also, these depths are beyond the 25- to 50-cm wetting depth of the present climate (Gile 1977). This means these calcic horizons were formed under different climatic conditions than the prevailing one. This also suggests the past climate was wetter than the prevailing one. The recalculated particle size distribution on a clay-free basis (see Table A2) showed lithological discontinuity at depths of 30 and 185 cm (see Figure V-4). The first lithological discontinuity appears to be the result of a different depositional environment than that of the time the interdune was formed. The surface horizon is richer in clay and silt (sandy clay loam) than the sandy horizon below. The blowsand soil material between 30 and 185 cm is of eolian origin. This is inferred from the well-sorted distribution of sand grains and their similarity to the fresh sand material (Boggs 1987). The second lithological discontinuity happened at 185 cm just below the sand material. This indicates the material below the 185-cm depth was formed under a different depositional environment than the material above it and the material between 30- and 185-cm depth has the same depositional environment. Based on radiocarbon dating of inorganic carbon in pedogenic carbonates, the age of soil material at 200 cm is 14,360 ±120 B.P. During this period of latest Pleistocene age, the climate was wetter and cooler (Galloway 1983; Hawley et al. 1976; Reeves 1973) than the later climate under which the soil material above 185 cm was formed (see Table A1). The material above 185 cm was not dated because it was hard to get carbonate crystals for C-14 dating since there were no prominent carbonate nodules or filaments in these horizons. The sand material between the 150- and 185-cm depth contained stage I carbonate, which, according to Gile et al. (1981), places it in the middle to late Holocene age. Holocene climate had an effective precipitation similar to that of the present arid, thermic-to-hyperthermic climate (Bull 1991). A good indication of surface stability, especially in soils of Pleistocene age, is the accumulation of silicate clay and secondary calcium carbonate. Soils on stable surfaces can have prominent argillic horizons (Gile and Grossman 1979). The clay content of soils developed on Pleistocene piedmont deposits exceed that of Holocene soils (Dohernwend 1991). The presence of argillic and calcic horizons in this profile suggests this surface is stable since it allowed moisture penetration necessary for clay illuviation and secondary calcium carbonate accumulation (Gile et al. 1981). The argillic horizon at a depth of 230 cm was engulfed completely by stage III carbonate.

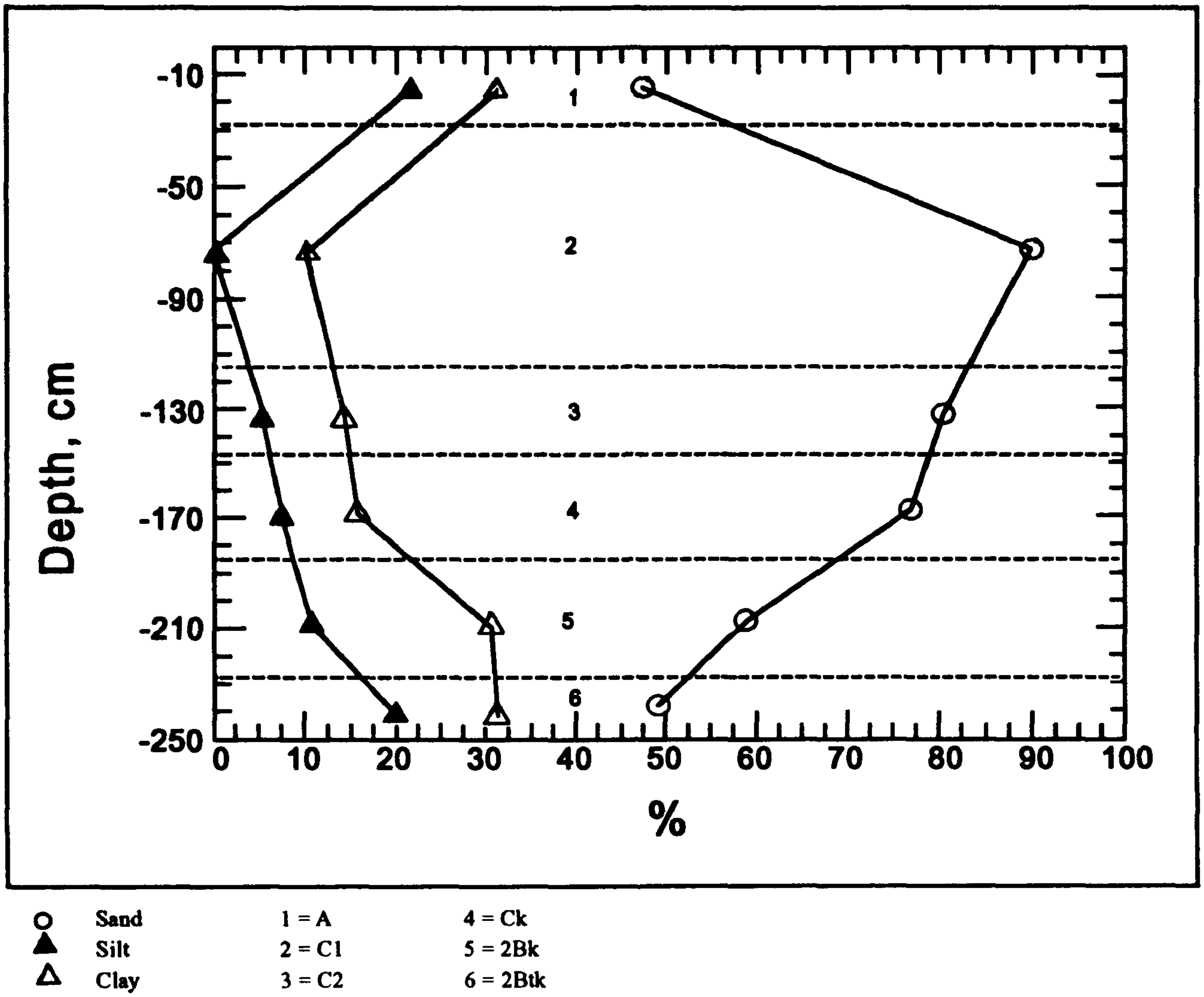


Figure V-3. Particle Size Distribution for Soil Profile 1

Soils with Bt, where the Bt has not been eroded or engulfed by carbonate, and K Horizon occur on Jornada II surface (Gile et al. 1981). This surface was designated as Jornada II because of the stage III calcium carbonate development (Gile et al. 1981).

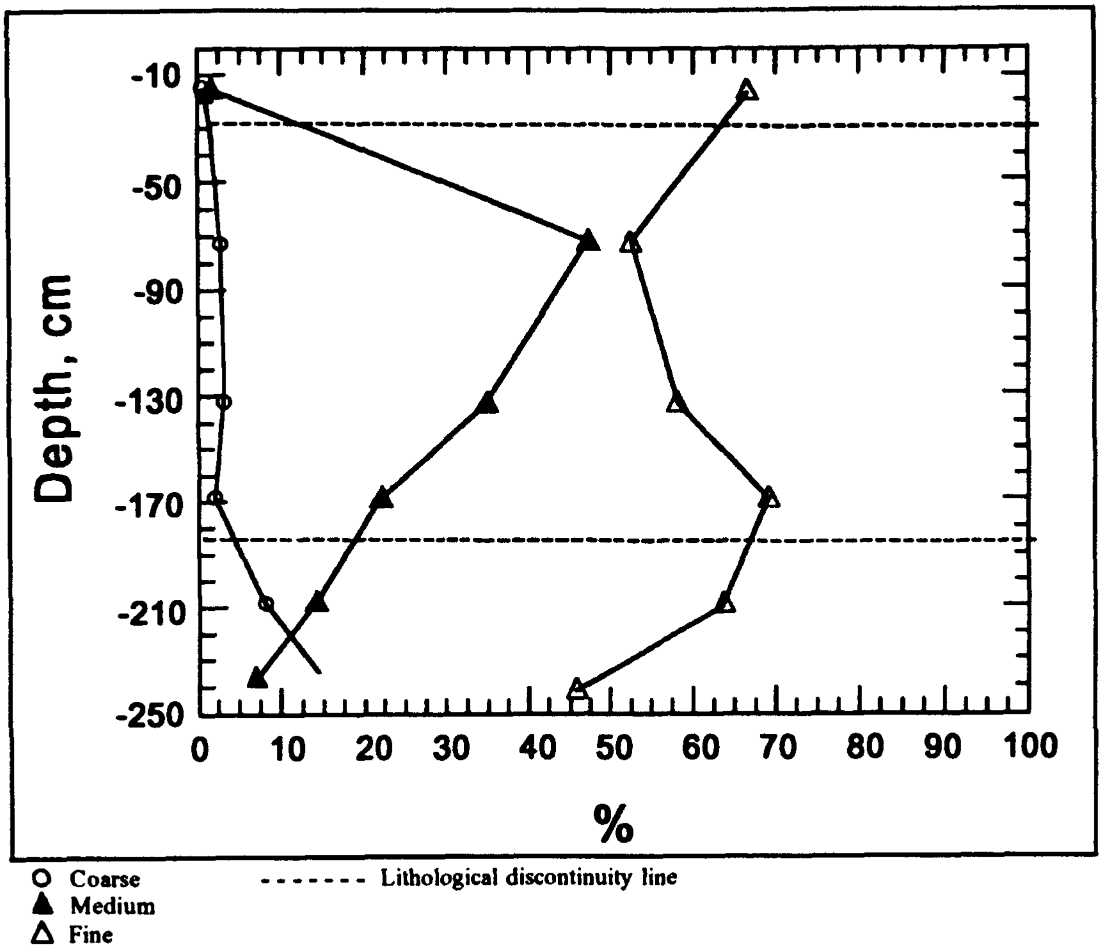


Figure V-4. Particle Size Distribution on a Clay-Free Basis for Profile 1

Pedon 2

Sand content is highest at the surface and decreases with depth to 200 cm (see Table A3). Below 200 cm it decreases and remains uniform (see Figure V-5). The first lithological discontinuity occurs at 200 cm (see Table A4) and the second one occurs at 230 cm (see Figure V-6). The horizons below 2 m are rich in carbonate but cannot be designated calcic horizons because they are less than 15 cm thick (Soil Survey Staff 1975). Clay content increased with depth until 200 cm and remained constant afterwards. The increase in clay content suggests illuviation was active in the upper 200 cm; again this is beyond the present wetting front. The wetting front for soils west of the Organ Mountains, with annual precipitation of 220-250 mm, ranges from 25-50 cm (Gile 1977). This indicates these soils formed in a cooler, wetter environment than exists today. The thick B Horizon could have resulted from the pluvial climates of the late Pleistocene. Soils with weak Bt and stage II carbonate horizons occurred on Isaacks' Ranch (Gile et al. 1981). The argillic horizon in Isaacks' Ranch soils suggests more effective precipitation was available for clay illuviation (Gile 1975). The argillic horizon of this soil profile contains calcium carbonate nodules of stage II. Therefore, this surface was designated as Isaacks' Ranch.

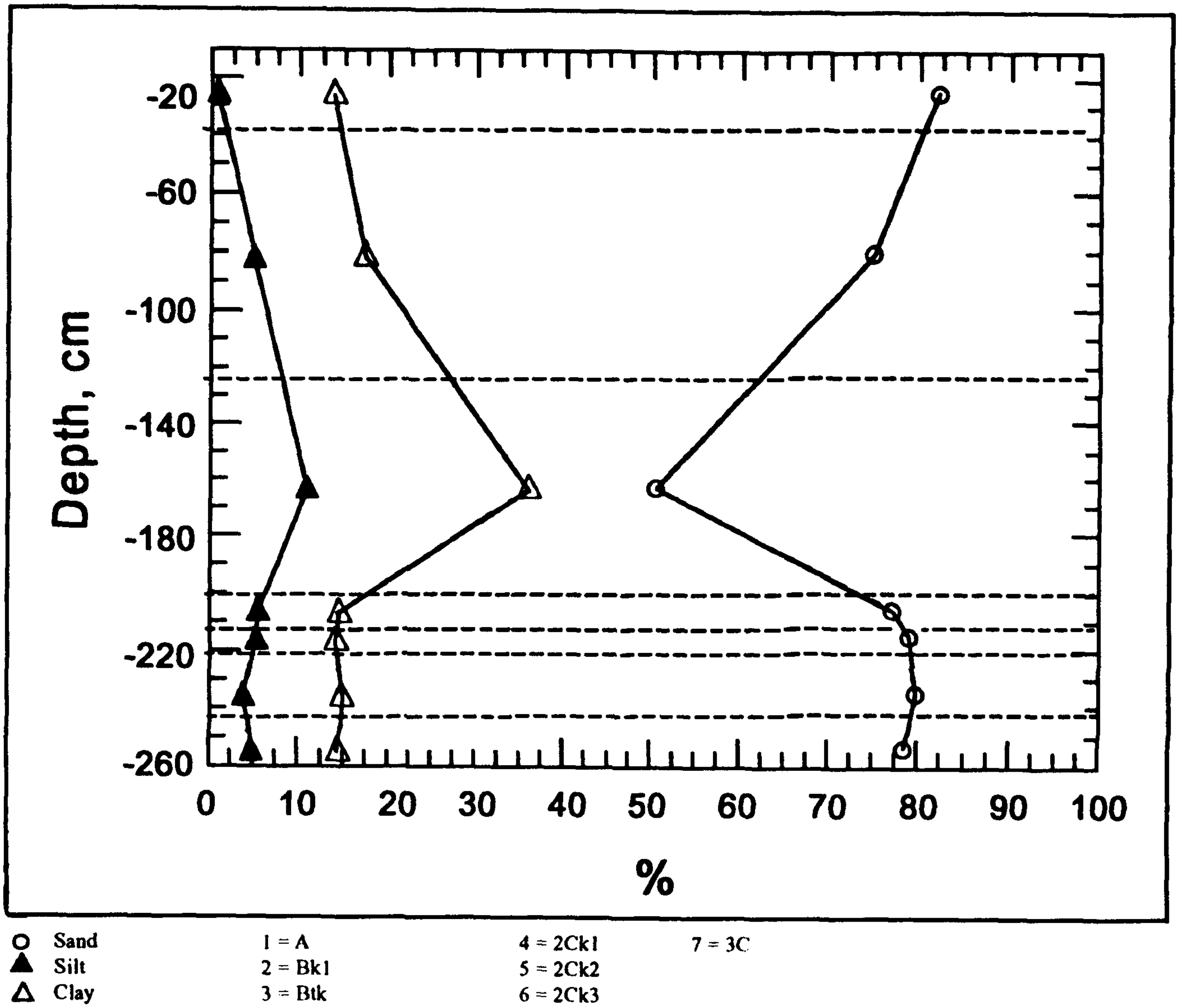


Figure V-5. Particle Size Analysis for Soil Profile 2

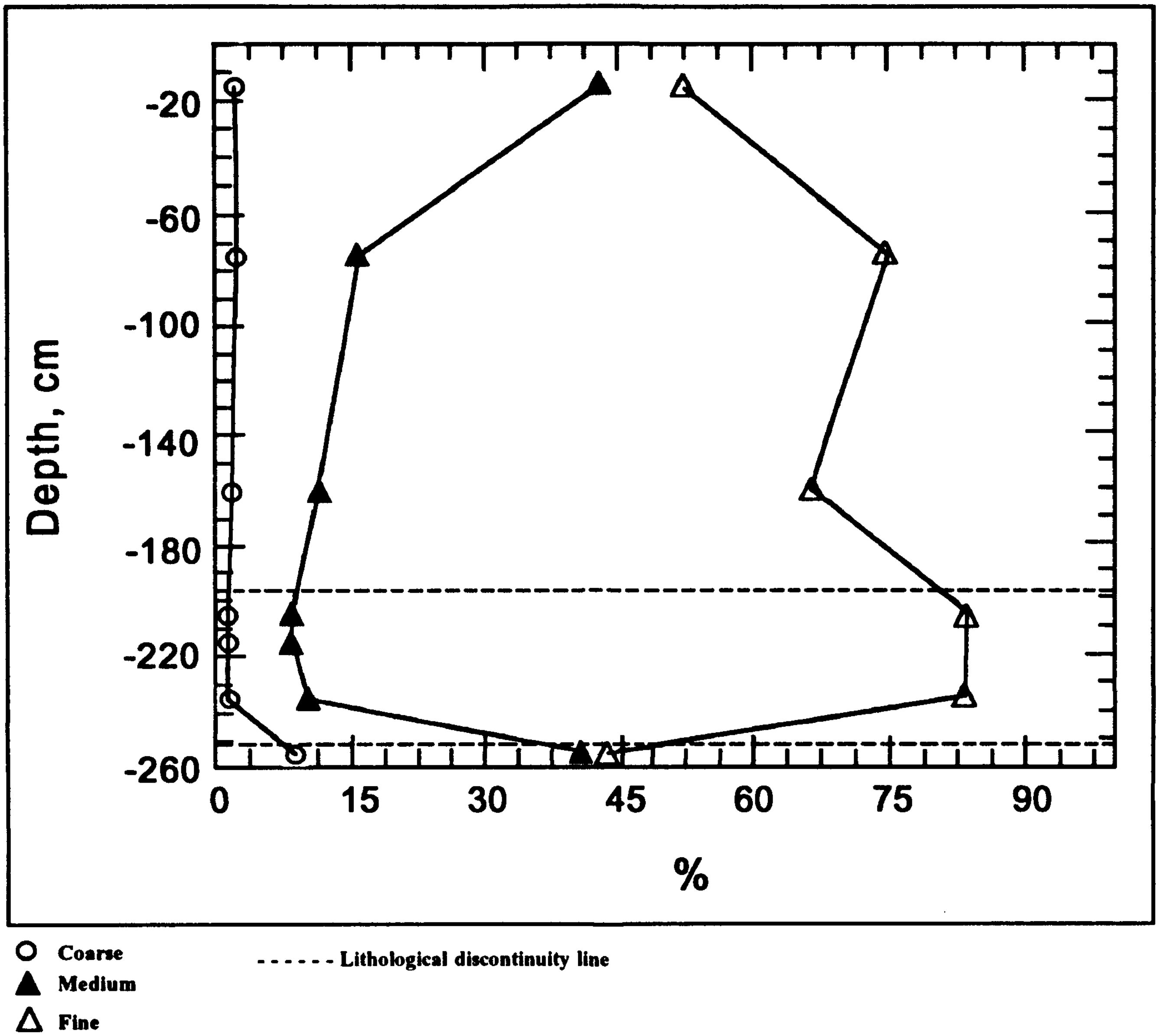
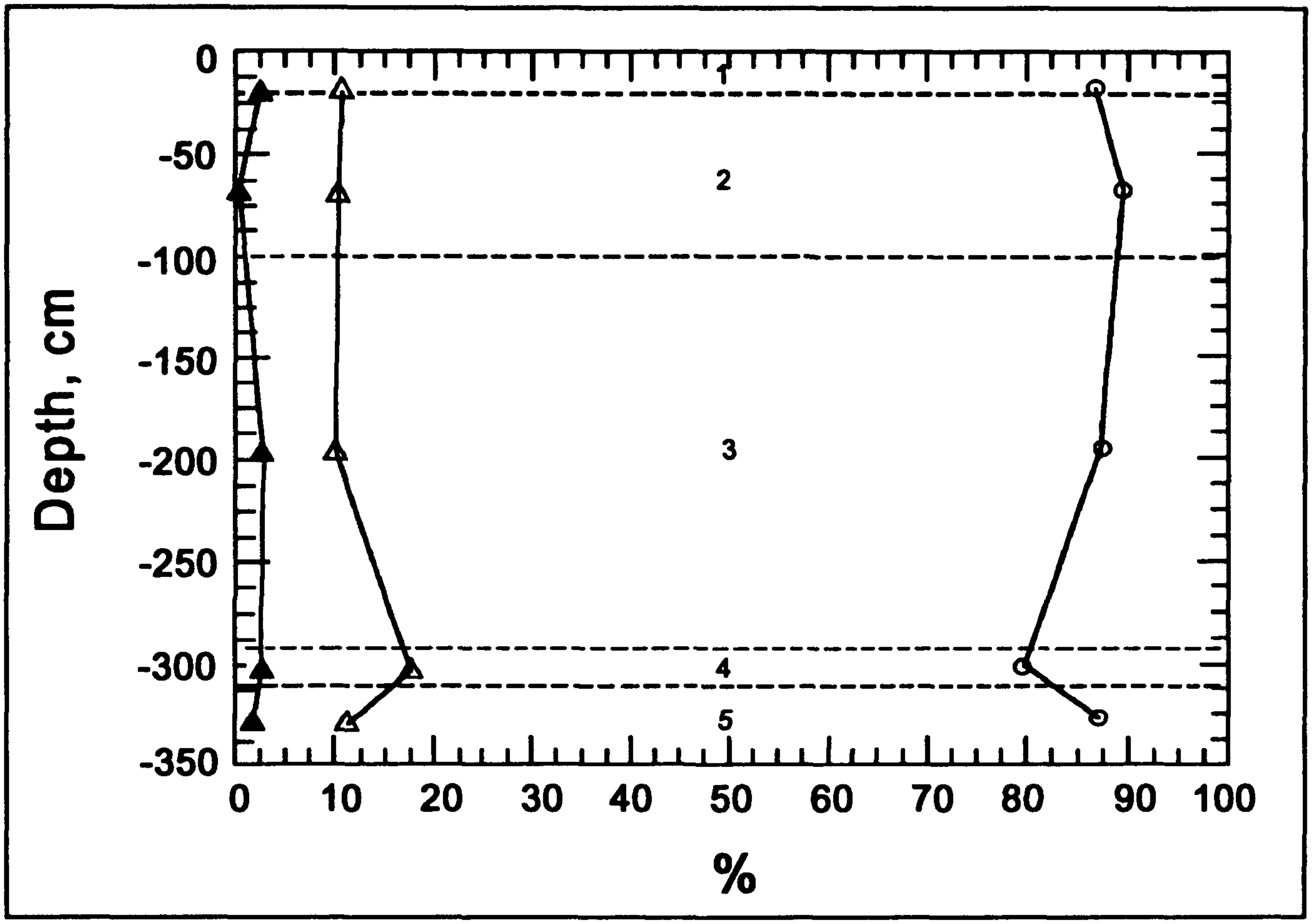


Figure V-6. Particle Size Distribution on a Clay-Free Basis for Profile 2

Pedon 3

The sand content was distributed uniformly throughout the profile (see Table A5). Clay content was uniform in the top 3 m, then increased below that depth (see Figure V-7).



Sand
Silt
Clay

1 = A
2 = C
3 = Ck
4 = 2Bk1
5 = 2Bk2

Figure V-7. Particle Size Distribution for Soil Profile 3

The dunes in this site are of 5 YR hue, as contrasted with the previous soils that had 7.5 YR. This is caused by a thin coating of oriented clay and associated iron oxides on the sand grains (see thin-section description). Most pedogenic carbonate, clay, silt, sulfates, and iron oxides in Holocene-age soils originated through external sources, mainly air-borne dust (Gile 1975; Gile and Grossman 1979).

Stage I carbonate was found in the thick eolian material overlying the stage III carbonate horizon. There was no stage II or an argillic horizon on top of the stage III carbonate horizon and there was a clear boundary between the thick sand material and the stage III carbonate horizon. Older carbonate horizons (of late Pleistocene) usually are deep in the profile, compacted, and subjected less to erosion and disturbance by the

soil biota than are the surface horizons (Gile et al. 1981). This suggests truncation took place in this site and the pedogenic horizons on top of the older carbonate horizon were truncated.

The wetter pluvial climates that lasted more than the interpluvial intervals together with the presence of unweathered dust in the soil profile helped in rapid pedogenesis. This caused weathering and translocation of the unweathered dust that accumulated in the upper soil horizons (Bull 1991). The thick eolian deposits on top of the stage III carbonate appears to be of Holocene age because of the stage I carbonates, minimal soil horizonation, poorly developed soils, lack of B Horizon, and little evidence of pedogenesis (Mayer et al. 1984; Dohrenwend et al. 1991).

Throughout much of the Quaternary, the bulk of eolian activity across the southwest Basin and Range Province occurred in discrete episodes of strong activity separated by intervals of relative inactivity and landscape stability (Dohrenwend et al. 1991)

Stage I carbonate horizons are a major feature of pedogenesis in the Holocene (Bull 1991). Stage I carbonate horizons are characteristic of Organ surface soils. The age of such horizons in the nearby USDA Desert Project, which is of similar terrain, parent material, and climatic conditions was found to be from 100 to 7000 B.P. (Gile et al. 1981). Stage I carbonate horizons occur in Holocene soils (soils younger than 7,500 years). Stage II, III, and IV carbonate horizons occur in Pleistocene soils (Gile 1975).

The stage III carbonate in this pit was 22,790± B.P. The material above the stage III carbonate horizon is believed to be of 7000 B.P. This indicates terrestrial materials present at this depth that was removed or truncated sometime between 23,000 and 7000 B.P. The beginning of the Organ deposition (7000 B.P.) is believed to coincide with the onset of the Altithermal interval (Gile and Hawley 1968). The Altithermal was a long drought that occurred during the middle Holocene (7000-4000 B.P.), according to Antevs (1955). Such a drought could have resulted in a reduced vegetative cover and consequently enhanced erosion. Benedict (1979) suggests the Altithermal was severe, felt in almost all the western United States, and that it consisted of two short, severe droughts (7000-6000 B.P.) and (6000-5500 B.P.).

The dated stratigraphic record of the Desert Project indicates the onset of a major period of landscape instability and erosion sedimentation during the this interval (Gile and Grossman 1979). Increased aridity and decreased effectiveness of vegetative cover in the area led to landscape instability, characterized by erosion-sedimentation, alternated with longer intervals of surface stability and soil development (Hawley et al. 1976; Wells et al. 1987). At the onset of aridity, the sediments yields would increase rapidly after the vegetative cover deterioration (Bull 1991).

Thus, dispersement of thick eolian deposits could have happened after the "long drought" (Altithermal interval) suggested by Antevs (1955). During the middle Holocene and Altithermal, pedogenic horizons on top of the stage III calcium carbonate were stripped off and were followed by rapid sand deposition, resulting in the formation of an Entisol. Stratigraphic, pedologic, and pollen studies in the Desert Project area suggest the erosion-deposition process could be the result of severe droughts like the Altithermal interval (Gile 1975). Blair et al. (1990) found that late Pleistocene and early Holocene sedimentation events in the Tularosa Basin are like those of the Desert Project area. Soils with no genetic horizons, such as Torripsamments, occur in very young alluvial and eolian deposits (Gile et al. 1981). Torripsamments occur in coppice dunes and consist mainly of C-Horizon material with no development of B Horizon (Gile 1975).

Holocene soils occur in dunes on basin floors and lower slopes of the fan-piedmont (Gile 1975). Pedon 3 occurs in the basin floor. As a result of active deposition in this profile, there is little pedogenesis.

Therefore, this surface was considered unstable until the deposition processes stopped. In the Jornada Basin of the Las Cruces area, Organ sediments occur near the basin floor (Gile 1975). Throughout the southwest Basin and Range Province, the Pleistocene-Holocene transition probably caused piedmont aggradation (Bull 1991).

The particle size distribution calculated on a clay-free basis (see Table A6) shows lithological discontinuity at a depth of 312 cm (see Figure V-8), suggesting a different depositional environment.

This surface was designated as Organ because of the stage I filaments and thick sand deposits.

Sedimentary Structures

There is no evidence for pedogenesis in the thick eolian deposits with the exception of the stage I calcium carbonate accumulation. This could have resulted in the obliteration of the eolian crossbed sedimentary strata in the upper, thick eolian material in profiles 1 and 3.

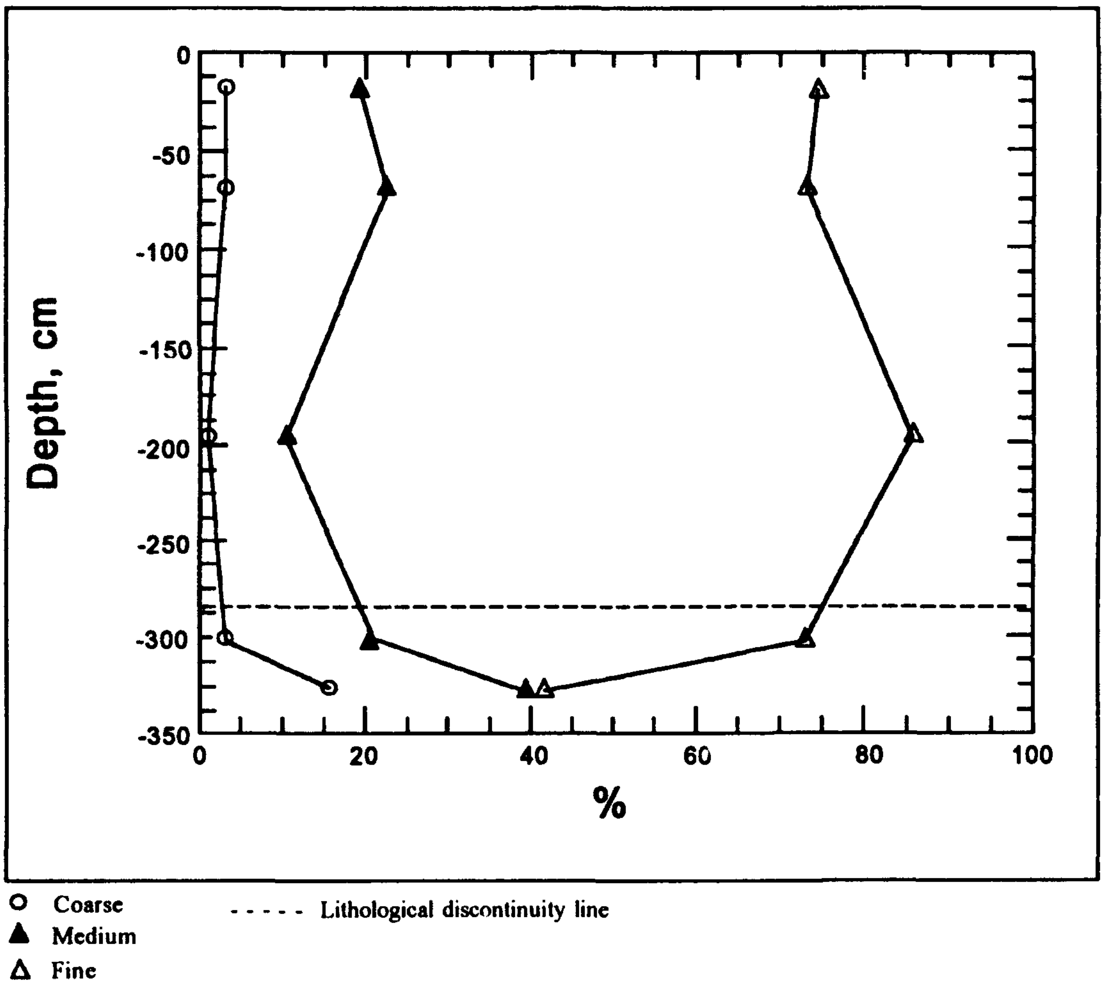


Figure V-8. Particle Size Distribution on a Clay-Free Basis for Soil Profile 3

Secondary Calcium Carbonate

Secondary calcium carbonate content increased with greater depth in profile 1. This suggests carbonate leaching is taking place. No regular pattern for carbonate distribution exists in profile 2, which reached its maximum value at the Btk Horizon. This could be related to the low permeability this argillic horizon possesses. Carbonate distribution was uniform for the upper part of profile 3 and reached its maximum at a depth of 290 cm. None of these calcic horizons will affect the soil profile classification because their upper boundaries are not within the 1-m limit (Soil Survey Staff 1975).

pH and Electrical Conductivity

Typical of southern New Mexico soils, pH values ranged from 7.8 to 8.2. Electrical conductivity values were low and none of the studied soils had saline soils, indicating these soils do not concentrate soluble salts, as is the case is in playa soils.

Organic Matter

The organic matter accumulation does not accord well with soil age. The organic matter accumulation on sand dunes usually is of historical age. Soil organic matter usually is related to soil properties of the upper horizons and landscape position (Gile et al. 1979). Organic carbon was highest at the surface for all studied soils. The A Horizon for profile 2 has enough carbon to qualify it as a mollic epipedon but the color is not dark enough to designate it as a mollic epipedon.

Mineralogy

Gypsum, sepiolite, and palygorskite usually occur in lacustrine environments of semiarid-to-arid regions. Commonly they are found in playa deposits and ancient lacustrine terraces (Singer 1989). Isphording (1973) concluded that sepiolite and palygorskite are found in marine and lacustrine sediments interbedded with chert, calcites, dolomites, and other nonclastic carbonates. Palygorskite-sepiolite groups usually occur in soils and lacustrine deposits of the Basin and Range Province and in the southern Great Plains Province (Parry and Reeves 1968; Bigham et al. 1980).

X-ray diffraction patterns of some selected samples showed that quartz, calcite, and feldspar are the dominant minerals in the studied soils. Minerals of lacustrine origin, such as palygorskite and sepiolite, were not found (see figures V-9, V-10, V-11).

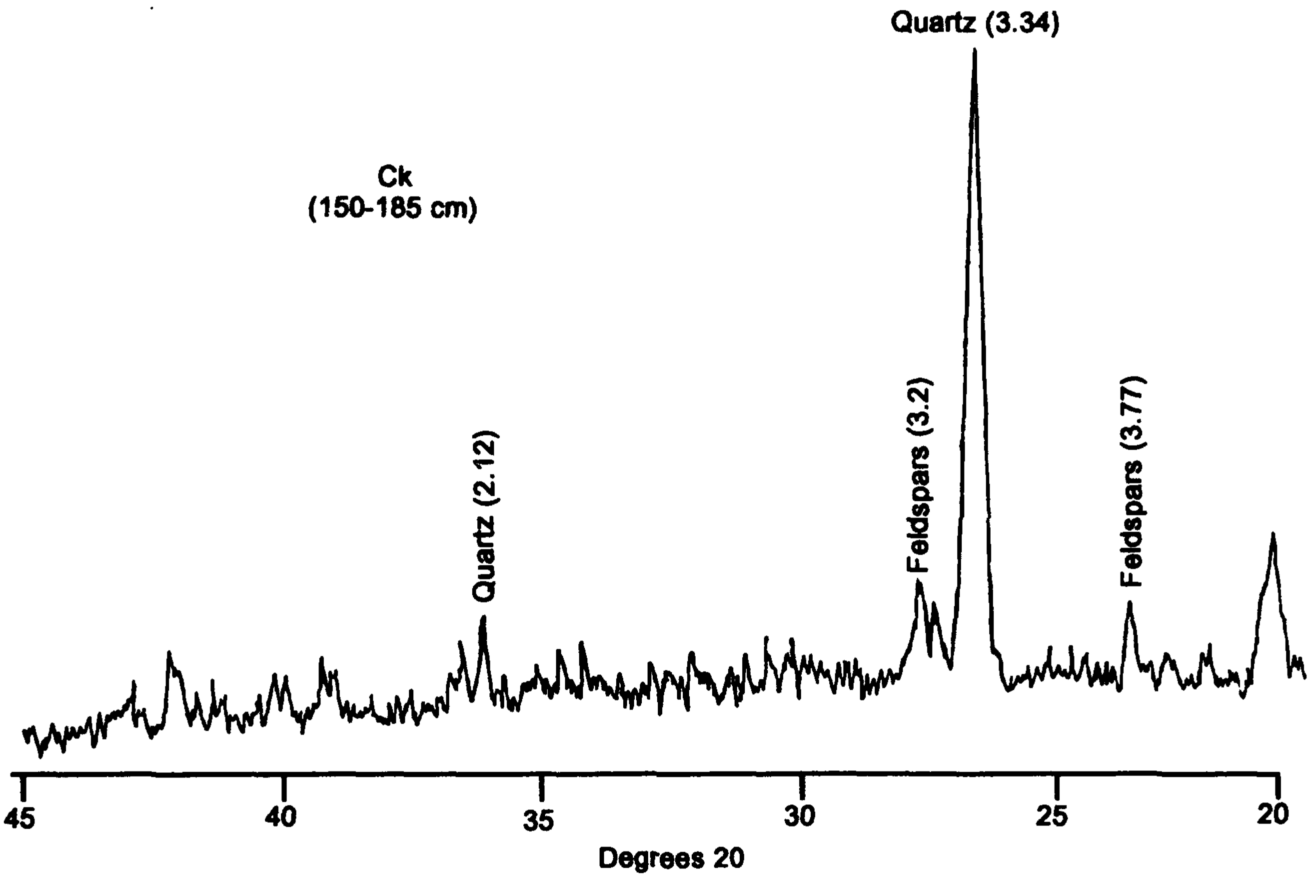


Figure V-9. X-ray Diffraction Patterns of Bulk Soil Sample for Profile 1

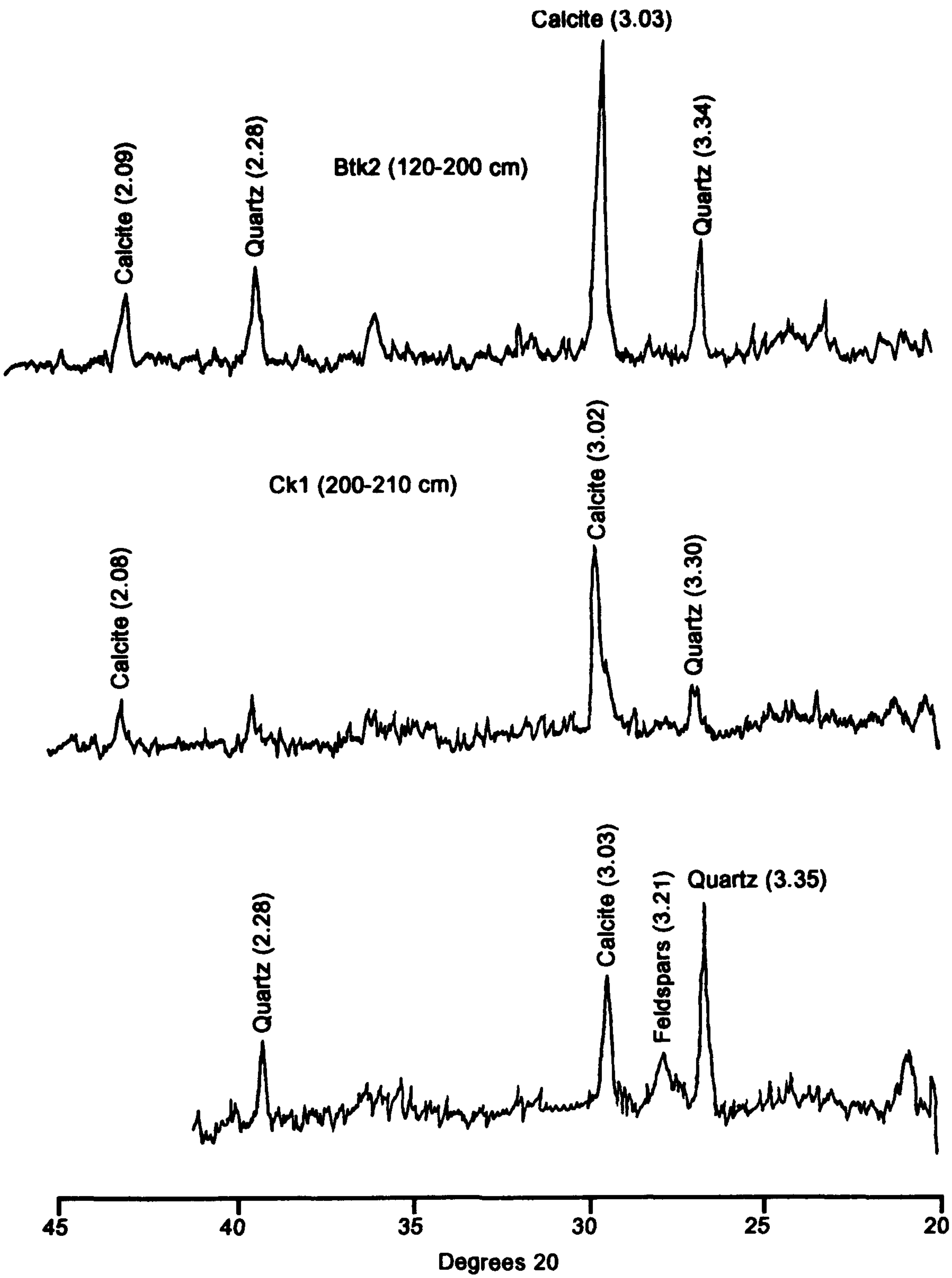


Figure V-10. X-ray Diffraction Patterns of Bulk Soil Sample for Profile 2

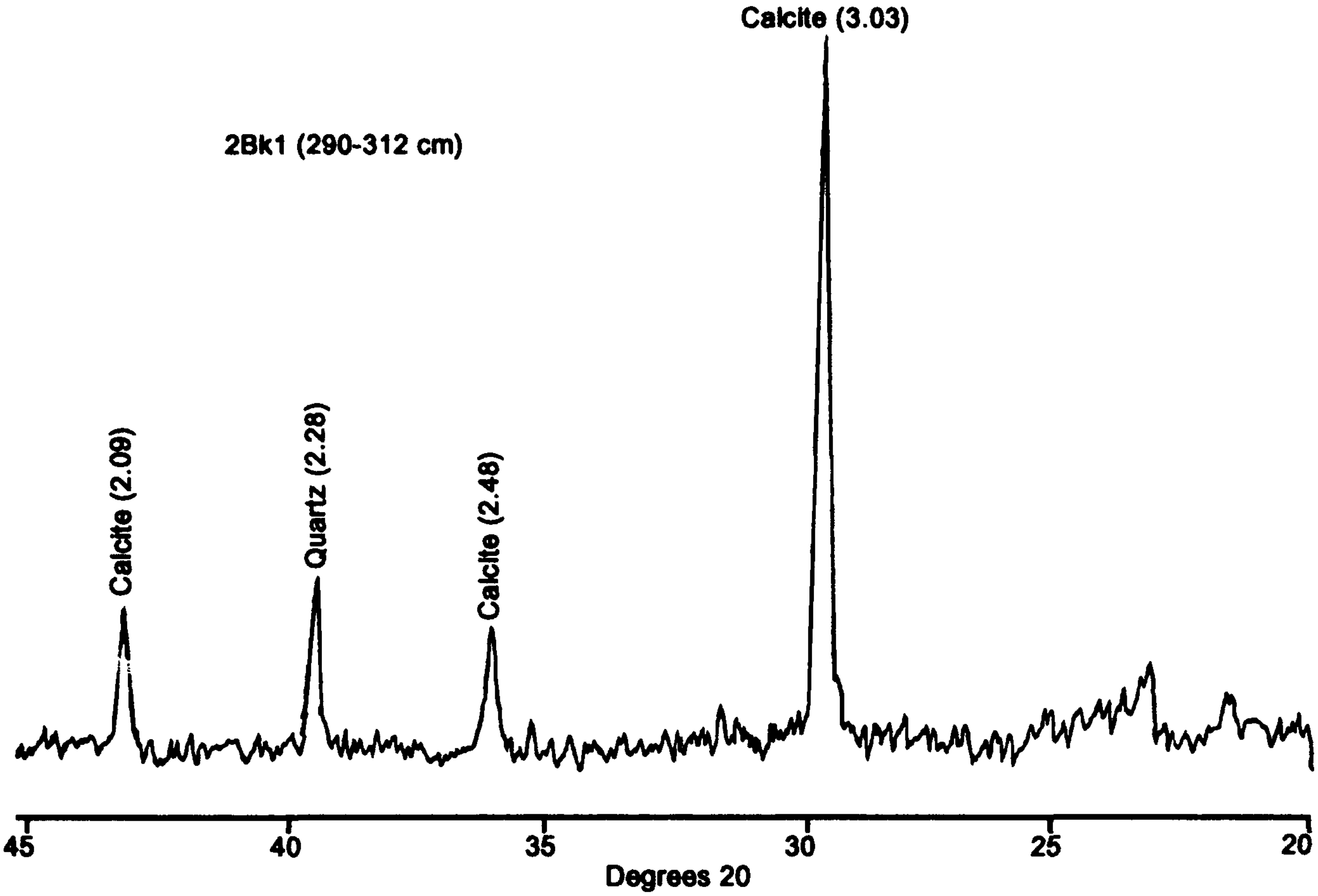


Figure V-11. X-ray Diffraction Patterns of Bulk Soil Sample for Profile 3

Soil Micromorphology

No evidence of fossils was found in the thin sections for the studied pedons. Clay films and associated iron oxides coating sand grains were observed in the surface samples. These were not formed in place; they most likely were deposited by wind from dust (Gile et al. 1981). The presence of these clay skins indicates the surface material is recent because the clay films still are preserved and were not leached down in the profile (see figures V-12, V-13).

The most common minerals found were quartz, rhyolite, plagioclase, and microcline. The rhyolite presence in a calcite matrix (see Figure V-14) suggests the carbonate originated from an external source, in this case atmospheric additions, since there is no evidence of a high water-table level. The secondary accumulation of calcium carbonate led to the scattering of the skeletal grains (see Figure V-15). No limestone material was found in the thin section, suggesting the detrital grains are igneous in origin. No evidence of significantly weathered minerals was found. This indicates a low chemical-weathering rate, which is typical for this area. It also indicates the silicate clay was not formed in the profile. As for the calcium carbonate, it appears that part was formed microbially (Monger et al. 1991) and the other came from external sources, such as calcareous dustfall (Gile and Grossman 1979).

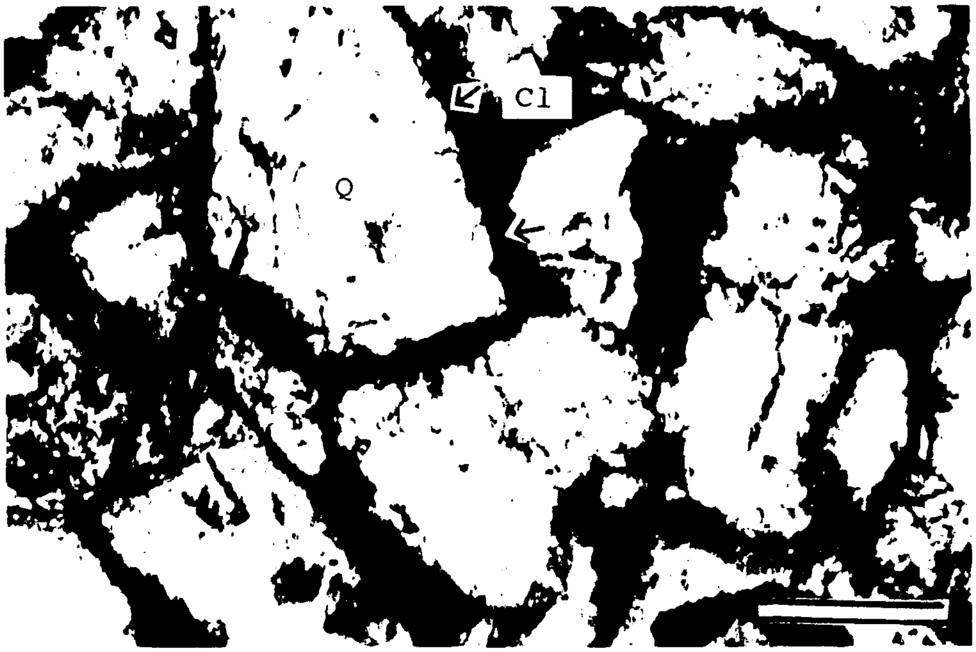


Figure V-12. Clay Skins (CL) Surrounding a Quartz Grain (Q) in the A Horizon of Profile 2 (Bar scale = 200 μm. PPL.)

Figure V-13. Clay Skins (CL) Surrounding the Sand Grains in the A Horizon of Profile 3 (Bar scale = 200 μm. PPL.)

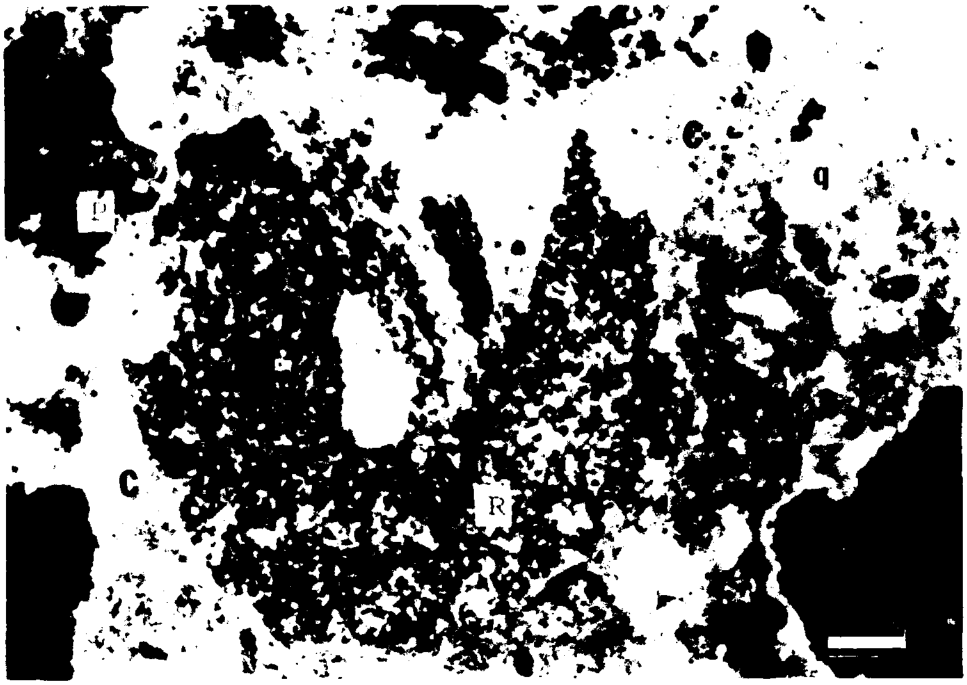


Figure V-14. Rhyolite (R), Plagioclase (P), and Quartz (q) in a Calcite Matrix in the 2Bk Horizon of Profile 1(Bar scale = 165 μm. XPL.)

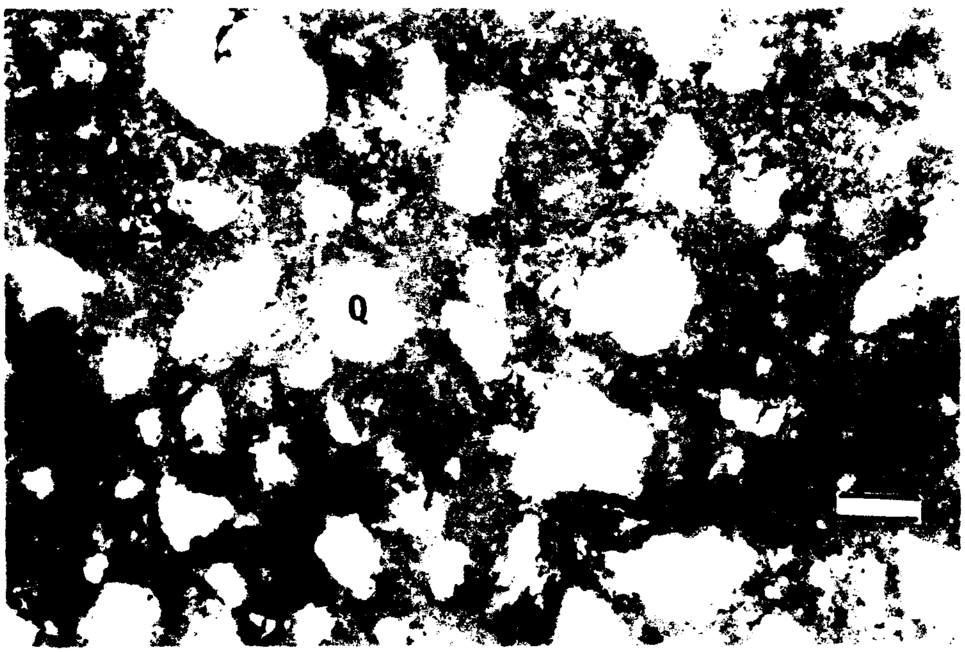


Figure V-15. Quartz Grains in a Stage III Calcium Carbonate in the 2Bk1 of Profile 3 (Bar scale = 165 μm. PPL.)

Stable Isotopes

Carbonate C-14 dating can verify relative ages from late Pleistocene through Holocene (Gile et al. 1981). The purpose of the radiocarbon isotope study was to establish a chronological sequence of soil development. C-14 soil carbonate ages were determined for samples of stage III carbonate development. The samples were obtained from pedon 1 at a 2-m depth and pedon 3 at a 3-m depth and a 2-m depth at the borrow pit. Stable carbon isotopes can be used as paleoenvironment indicators (Cerling 1984; Cerling et al. 1989). Also, the carbon isotopes ratio $^{13}C/^{12}C$ and oxygen isotopes ratio $^{18}O/^{16}O$ were determined for the same samples.

The isotopic composition of oxygen ^{18}O in pedogenic carbonate is controlled by the amount of ^{18}O in meteoric water (precipitation) (Hays and Grossman 1991). The amount of carbon ^{13}C is controlled by the soil respiration rate and the relative abundance of C-3 and C-4 plants (Cerling 1984; Quade et al. 1989). Higher respiration rates suggest a lighter pedogenic carbonate isotopic signal and a C_3 plant type. Lower respiration rates indicate less negative $\delta^{13}C$ and C_4 plant types (plants under stress) (Quade et al. 1989). The $^{13}C/^{12}C$ signature indicates the plant type in the late Pleistocene (26,000-23,000 B.P.) was dominated more by C-3 plants than during the late Pleistocene-early Holocene (13,000 B.P.), which was probably dominated by C-4 grasses (see Table B1).

Paleotemperatures might be established from the amount of ^{18}O in pedogenic carbonate. This is possible because there is a strong relationship between mean annual temperature (MAT) and the amount of ^{18}O in the meteoric water (Hays and Grossman 1991). Soil carbonate paleotemperatures in the study area were based on the relationship between MAT and ^{18}O in meteoric calcite suggested by Hays and Grossman (1991). MATs were cooler in the late Pleistocene, possibly ranging from 10-12.5°C, whereas in the late Pleistocene-early Holocene MATs averaged about 15°C. Table B4 summarizes the isotope analysis results.

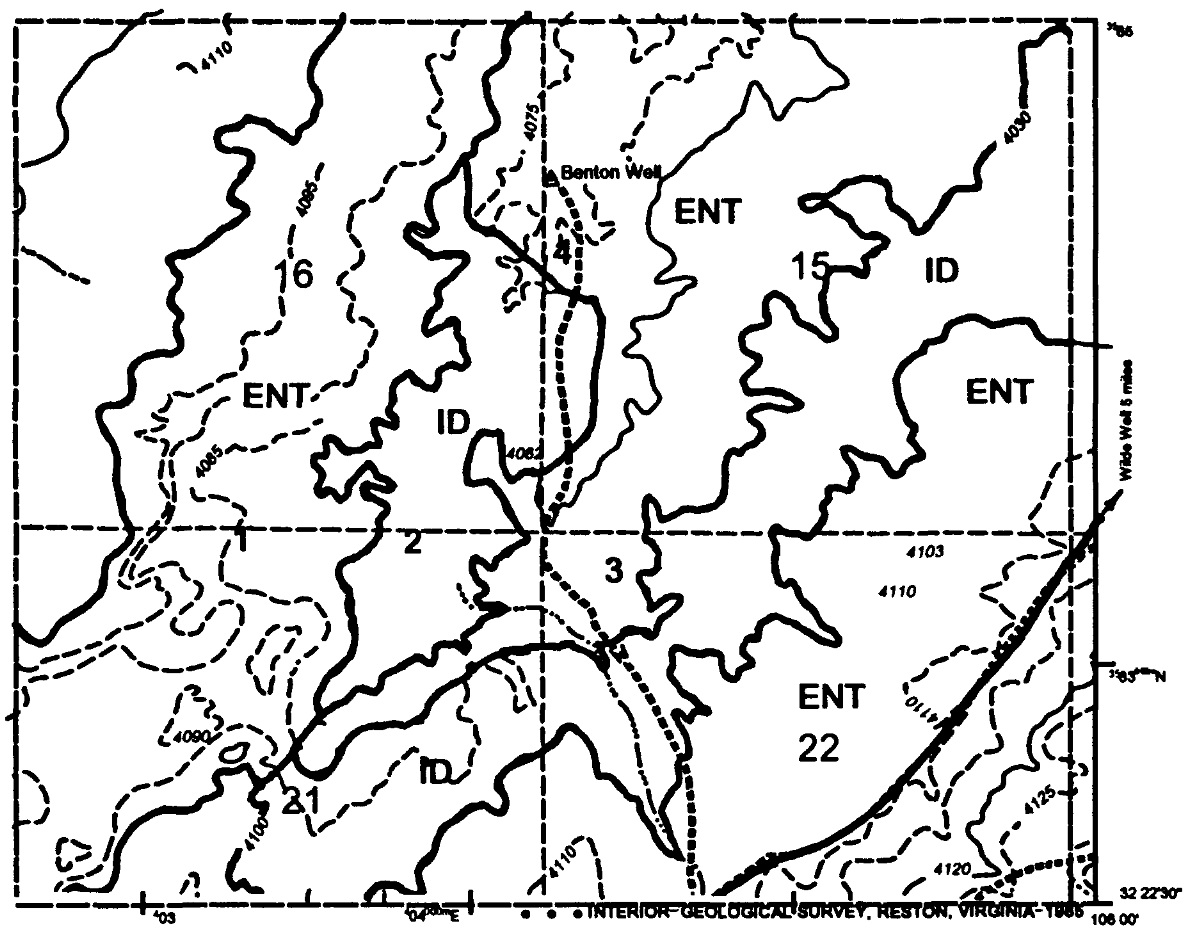
These results are consistent with Galloway (1983), who suggested temperatures in the southwestern United States during the late Pleistocene were 10°C lower than present ones.

Geomorphology

Geomorphic surface mapping helps in evaluating the impact of climate changes on soil development and landscape behavior (surface vulnerability). Mapping alluvial geomorphic surfaces also greatly affects ground water recharge, suitability of soils for agriculture and irrigation, and archeological studies (Bull 1991). A topographic map (1:24,000 scale) and satellite images were used to delineate geomorphic surfaces. Field examination of topographic features, soil profile studies and descriptions, augerholes, and changes in vegetation patterns also were used to assist in producing the geomorphic map (see Figure V-16). Mapping geomorphic surfaces and their related soils includes the comparison of soil features for different landscape positions and depositional processes (Gile et al. 1981).

Extensive intermontane basin floors and adjacent piedmont slopes are the major geomorphic features of the area (Hawley 1992). Piedmont is a sloping surface that connects the mountain to the adjacent plains (basin floor) (Ritter 1986).

The basin's major deposits are alluvial. The major geomorphic surfaces are coalescent fan-piedmonts (bajadas) and basin floor alluvial plains. Sandy eolian deposits are extensive locally (Hawley 1992).



ENT = Typic Torripsamments
ID = Typic Haplargids
1, 2, 3, 4 = Profile Locations

Scale 1:24000

Figure V-16. Major Soils of the Study Area

Geomorphic surface mapping was based on the soil morphology and, in particular, the soil carbonate depth and morphology, argillic horizon presence, and sand dune strata. Gile et al. (1981) defined the geomorphic surfaces of the USDA Desert Project (see Table B2), and since the study area is in the Mexican Highlands section of the Basin and Range Province, as was the Desert Project, the geomorphic surfaces were classified using their criteria. The major geomorphic surfaces of the area are Jornada II, Issacks' Ranch, Organ, and the historical Coppice dunes (see Figure V-16). The Jornada II surface was identified by the presence of stage III calcium carbonate, Issacks' Ranch by the presence of argillic horizon and stage II calcium carbonate, and the Organ surface by the stage I calcium carbonate. Soils developed on the Jornada II surface were classified as Typic Haplargid. Soils developed on the Issacks' Ranch surface were classified as Typic Paleargid. Strongly developed Haplargids and Paleargids are common in soils developed on Pleistocene piedmont deposits (Dohernwend et al. 1991). The Organ surface and historical dunes that occupied the basin floor and were classified as Typic Torripsamments (see Table B3) show the geomorphic surface age and physiographic positions.

The degree of soil development is related to the study area's geomorphic surface age. Aridisols (Typic Haplargids) developed on the older and more stable surfaces while Typic Torripsamments developed on younger and less stable surfaces.

The basin can be considered an externally drained semibolson, as Peterson (1990) defined a bolson except the basin does not have playas or pluvial lake features. Lacustrine landforms do not occur in semibolsons unless the area was covered by an arm of a deep pluvial lake (Peterson 1981).

Summary and Conclusion

This study was conducted on McGregor Range at the Fort Bliss Military Reservation in southern New Mexico. The study area represent an intermontane basin that contains eolian, fan-piedmont, and possibly lacustrine deposits that could contain climatic information relevant to archaeological and paleoenvironmental studies of the nearby Hueco Mountains. The goals of this research were (1) to unravel the area's geomorphic history by mapping the landscape surfaces and perceiving the depositional environments and climatic changes, and (2) to establish a relationship between soil geomorphic features and soil genesis and classification. Three hypotheses were formulated and tested in order to achieve this goal: (1) The basin was occupied by a lake during the late Pleistocene, (2) the basin represents a marshland site, and (3) the basin represents an alluvial plain.

Late Pleistocene Lake Hypothesis

Satellite data obtained by Fort Bliss Directorate of Environment suggests the presence of a paleolake in McGregor Range, northeast of the town of Orogrande. The site could contain significant climatic information pertinent to archaeological studies. The stratigraphic record shows no evidence of lamination, interbedded clay, ripple marks, fossils, or evaporite minerals. These stratigraphic features usually are associated with lacustrine or playa sediments. The basin deposits were thick, while common lacustrine deposits are thin. Topographically the study area cannot be a finger or a part of Lake Otero, since the maximum elevation of Lake Otero was 1,204 m, while the lowest point in the study area is 1,240 m. No evidence of old shorelines, wave cut benches, terraces, or any other geomorphic feature of a lake was found. It appears that this site was not occupied by a lake during the late Pleistocene, as thought earlier.

Marshland Hypothesis

Pollen analysis was used to locate any marshland grasses, such as cattail, but none were found. Mottles, which indicate reduced conditions as a result of a high water table, were not found either. This indicates the basin was not a wetland or marshland in the late Pleistocene period.

Basin Floor Alluvial Deposits Hypothesis

Particle size analysis on a clay-free basis indicated there was a change in depositional processes in the studied sites. The depositional environments are not lacustrine or ephemeral nor of wetland or marshland origin. The best scenario that fits this study site is a distal alluvial fan deposit and a basin fill with a variety of sand dune types and other eolian forms.

The major geomorphic surfaces of the area are Jornada II (JII), Issacks' Ranch (IR), and Organ (OR). Soils developed on the JII surface were classified as Typic Haplargid, IR soils were classified as Typic Paleargid, and OR soils were described as Typic Torripsamments.

Because soils developed on older geomorphic surfaces does not always mean they are older and more developed than those developed on younger surfaces. Paleargids are more developed than Haplargids and they occurred on a younger geomorphic surface. The Paleargids were developed on the late Pleistocene IR surface, while the Haplargids were developed on the late Pleistocene JII surface. Other factors are incorporated, among these is the landscape position where more effective precipitation and leaching resulted in the development of the thick argillic horizon and well-developed Aridisol.

Climate changes that took place in the late Pleistocene-early Holocene influenced the soil-forming processes in the area through changes in vegetation and effective precipitation. These changes influenced landscape stability and consequently erosional-depositional patterns. As a result, well-developed Aridisol (Typic Haplargid) were found on the stable and old sites. Torripsamments were found on the younger and unstable sites.

Carbonate horizons were deeper for late Pleistocene soils, suggesting these soils were formed under more effective precipitation than the Holocene soils.

Eolian and Fluvial processes are the major factors in the basin's landscape development.

No sedimentary structures (eolian cross beds) were preserved. This is attributed to the incipient development of stage I Calcium carbonate in pit 3.

Late Pleistocene soils have argillic and stage II and III calcium carbonate, while Holocene soils have only stage I and no argillic horizons.

Coppice dunes are the major eolian accumulation in the study area. They occur in the basin floor and lower piedmont slopes.

This study provides an idea about the nature of desert landscape changes and soil development as related to climate. Further studies are needed in soil genesis and geomorphology in order to better utilize our resources and comprehend our soils and environment and to develop better techniques in dating Aridisols.

Chapter VI

RADAR ANALYSIS OF THE FORT BLISS STUDY AREA

By John Kipp

Side-looking airborne radar (SLAR) data were obtained for the study area in an attempt to delineate subsurface calcrete layers. Although this object was unsuccessful, SLAR image analysis indicated radar reflectance values within a scene were related to dune size differences.

The survey was conducted by the USGS in 1989 using radar in the X-Band (λ= 2.40-3.75 cm) with depression angles ranging from 11° to 32° with a south-facing direction. Aircraft altitude was 39,000 feet above sea level, and spatial resolution of the images was 10 m. The 8-bit data were stored on magnetic tapes and analyzed in the Digital Mapping Laboratory at NMSU.

The ground-penetrating capabilities of radar have been useful in studies as diverse as soil mapping projects, archaeological investigations of buried structures, and locating underground pipelines (Teng 1985; Young et al. 1988; Mellett 1990). Detailed subsurface imaging with radar usually is done with a portable ground-based system that is designed to differentiate media at depths ranging from 0.5 m to 30 m mainly from differences in electrical conductivity (Campbell 1987). However, radar systems used in pipeline applications are not good at distinguishing natural horizontal strata (Young et al. 1988).

SLAR data were obtained instead because of its low cost and ready availability. Long (1975) found that airborne radar images may display relief variations in the landscape better than aerial photographs. Radar signals beamed to the earth's surface by aircraft are partially reflected back to a receiver, and the manner in which the signals are attenuated during transit can be measured. Although SLAR may have a surface-penetrating component, the most important influence on return signal strength on the targeted terrain is surface roughness relative to the radar wavelength (Siegal and Gillespie 1980; Kipp 1992). A rough surface tends to scatter energy in all directions with some of that energy being reflected back to the receiver, resulting in brighter pixels on the image. Alternatively, a smooth surface reflects the radar beam more uniformly away from the receiver, thus yielding darker pixels.

Radar images of certain areas on Fort Bliss were compared with corresponding geomorphic field maps. Although some mapping unit contacts could be delineated by image tone changes, it was determined that SLAR data alone could not be used as a mapping tool. Additionally, areas with known depth and extent of indurated caliche could not be distinguished positively by radar return signals attributed to reflection from a subsurface stratum. Of interest, however, was the apparent relationship between image brightness and dune size.

In Figure VI-1 a portion of the fault complex mapping unit is evident as a north-south trending dark gray swath near the center of the photograph. The considerably brighter area surrounding the fault complex is the main level of the La Mesa basin floor. Two prominent black spots to the left of center are grasslands. From a field check done in this area, it was noted that coppice dunes of the La Mesa surface were much larger (and higher) than the fault complex dunes. The interpretation offered for the brighter response is that the area for radar reflection back to the receiver off the north-facing dune slopes is larger. In other words, with larger, steeper dunes there is a greater likelihood that at some point on the dune slope the emitted and reflected radar

beams will be close to a line normal to the dune surface, resulting in strong return signals. With the smaller, more gently sloping dunes in the fault complex there is less possibility of an "ideal" radar-slope geometry configuration, and it would be expected that more of the radar beams would be bounced away from the receiver. The dark grasslands are predominantly flat and without dune development and so appear black in the image (almost no radar return reflection). Old Coe Lake and the lake bed sediments around it (see Figure VI-2) also exhibit a dark response as a result of the flatness of the terrain, while the brighter tones indicate dunes on the basin floor. A similar image is produced for the southwestern part of training area 5B (see Figure VI-3).

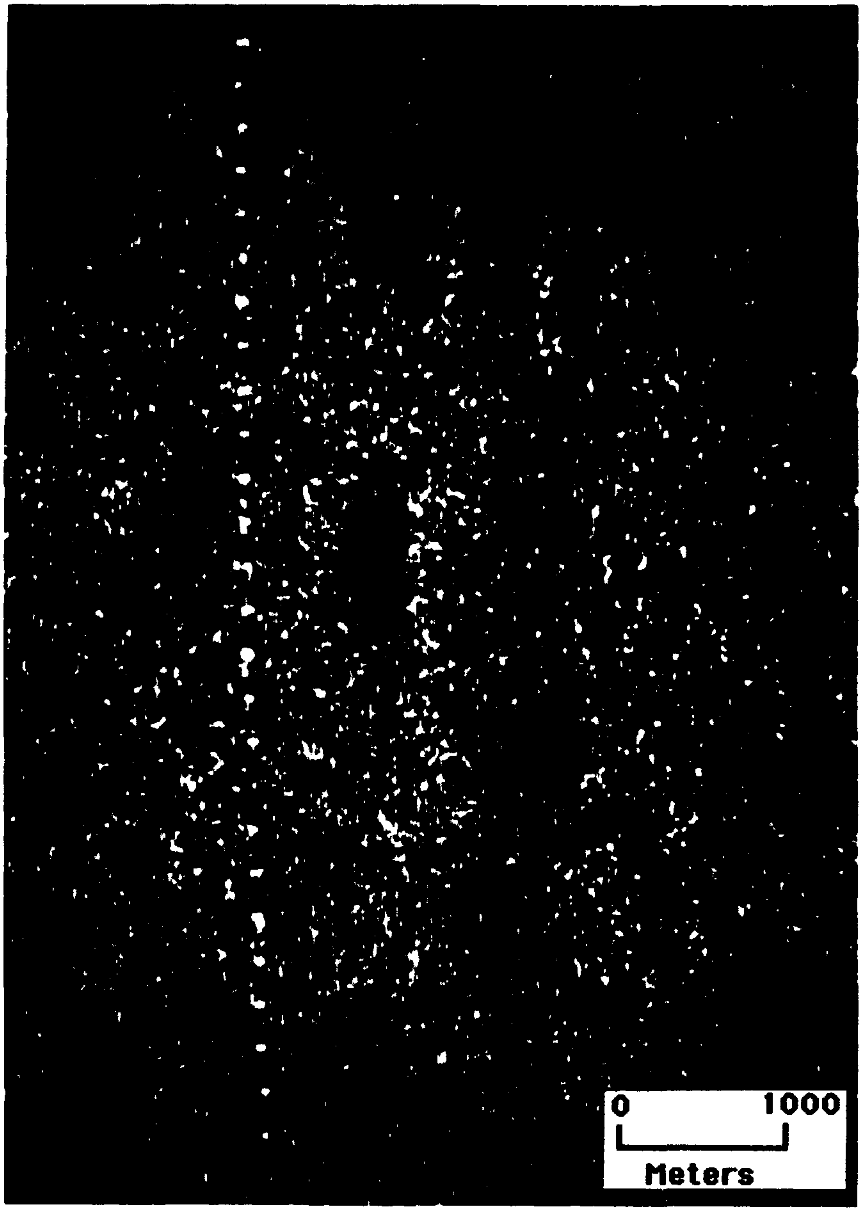


Figure VI-1. Photograph of SLAR Image Near Center of Training Area 1B, Fort Bliss South (Image is oriented with north up.)

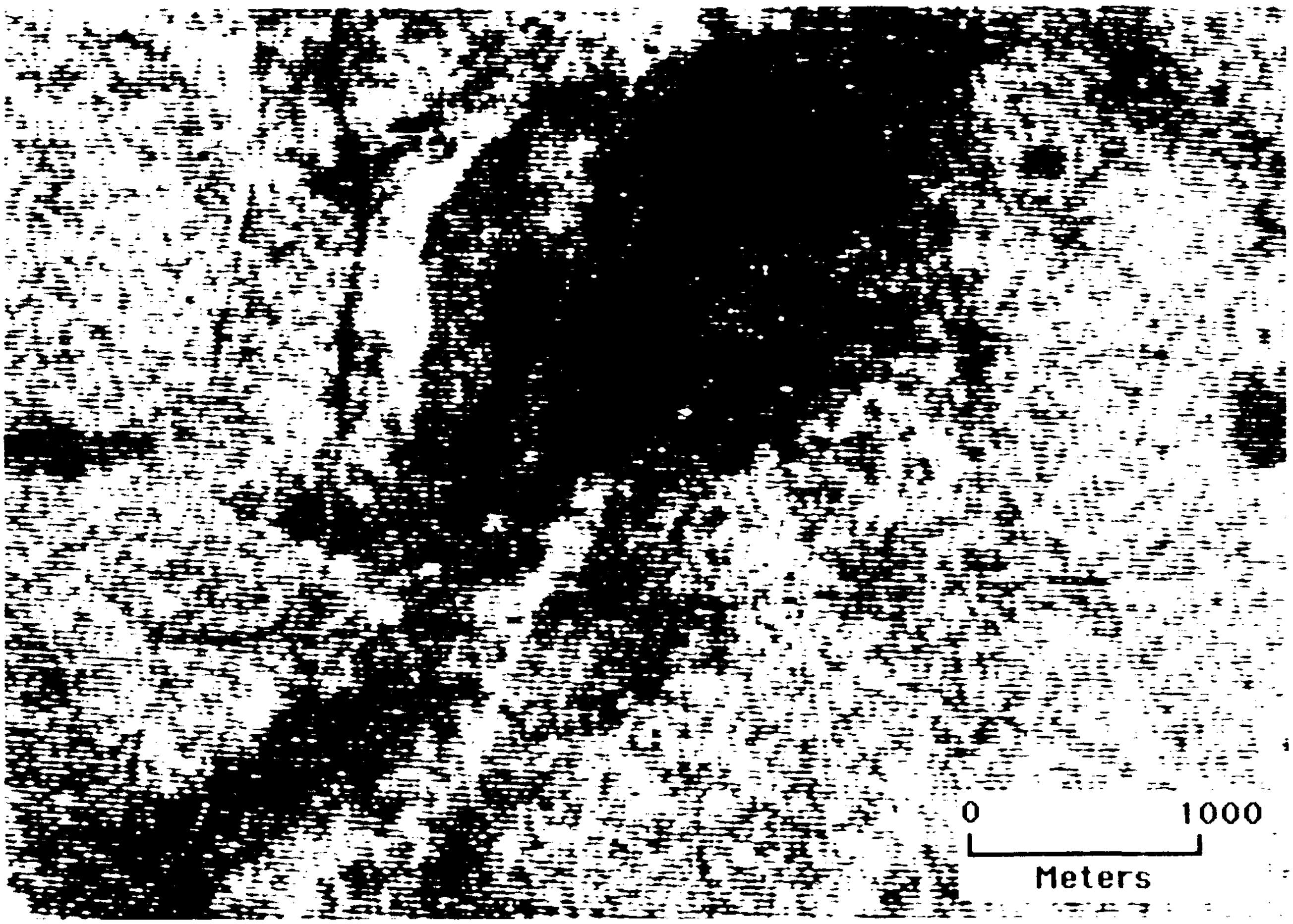
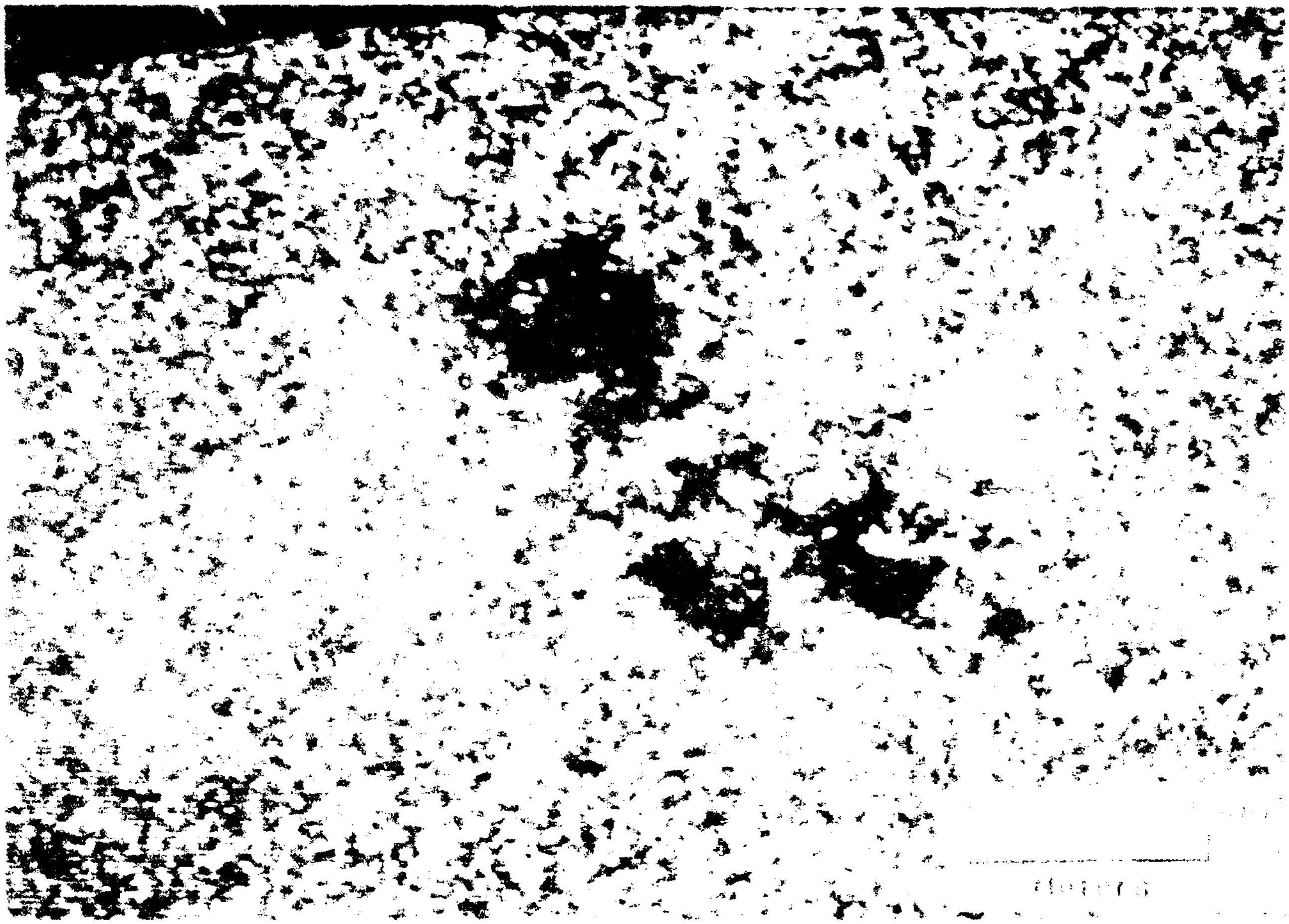


Figure VI-2. Photograph of SLAR Image of Old Coe Lake on the Western Margins of Training Areas 4A and 4B, Fort Bliss North (Image is oriented with north up.)

SLAR data was found to be useful in detecting major abrupt changes in topographic relief in certain locations that otherwise were not noticeable in aerial photographs. The mapping of subsurface calcrete layers possibly could be accomplished with a portable ground-based imaging radar or a seismic system designed for shallow work.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Part II

LATE QUATERNARY CLIMATIC AND ENVIRONMENTAL CONDITIONS

Chapter VII

STABLE ISOTOPES IN PEDOGENIC CARBONATES OF FAN-PIEDMONT SOILS AS AN INDICATOR OF QUATERNARY CLIMATE CHANGE

By H. Curtis Monger, David R. Cole, and Thomas H. Giordano

Abstract

Stable carbon and oxygen isotopes in soil carbonates contain information about climate change and the biogeomorphic responses to climate change. Calcic soils formed on alluvial fans surrounding the southern Organ and northern Franklin Mountains provide an isotopic record of much of the late Quaternary. Five study sites show lateral consistency in their pedogenic isotope record. $\delta^{13}C$ values are isotopically heavy in the late Pleistocene and shift to more negative values by the middle Holocene. This shift implies a change from C-4 dominated grassland to C-3 desert scrub vegetation between 9 and 7 ka. Predictions of mean annual temperatures based on $\delta^{18}O$ values of young pedogenic carbonates are similar to historic records. $\delta^{18}O$ values suggest late Pleistocene temperatures were similar to current temperatures but middle Pleistocene temperatures were around 5°C cooler.

Introduction

Stable isotopes in pedogenic carbonates are becoming increasingly important indicators of terrestrial paleoclimatic conditions (Cerling 1984; Amundson et al. 1989; Quade et al. 1989; Kelly et al. 1991; Mack et al, 1991). Buried soils on alluvial fans in southern New Mexico provide a good environment for studying the isotopic composition of pedogenic carbonate because (1) soils occur that have formed in igneous parent materials, thus assuring no contamination from older marine limestones, and (2) soils are buried deeply enough to prevent contamination by younger carbonates.

The $\delta^{13}C$ in pedogenic carbonates reflects soil respiration rates and the relative abundance of plants with C-4 and C-3 photosynthetic pathways (Cerling 1984; Salomons and Mook 1986; Quade et al. 1989). Respiration rates control the amount of isotopically heavy atmospheric CO_2 that diffuses into the soil. Thus, soils having actively respiring plants causing high soil respiration rates should have pedogenic carbonates with more negative $\delta^{13}C$ values than soils with lower respiration rates. Secondly, soils with abundant C-3 plants, which respire isotopically light CO_2, should have lower $\delta^{13}C$ values than soils dominated by C-4 plants.

The $\delta^{18}O$ in pedogenic carbonate largely is inherited from local meteoric water (Yurtsever and Gat 1981; Cerling 1984). Because the isotopic composition of meteoric water is a function mean annual temperature (Dansgaard 1964; Yurtsever and Gat 1981), pedogenic carbonates may contain information about mean annual temperatures that existed when calcite crystals precipitated (Hays and Grossman 1991).

In this study, three exposures containing well-preserved buried soils were analyzed for their isotopic composition. In addition, the laminar calcrete material that formed atop a petrocalcic horizon was analyzed because of the possibility that such material could contain a high-resolution record of terrestrial calcite accumulation.

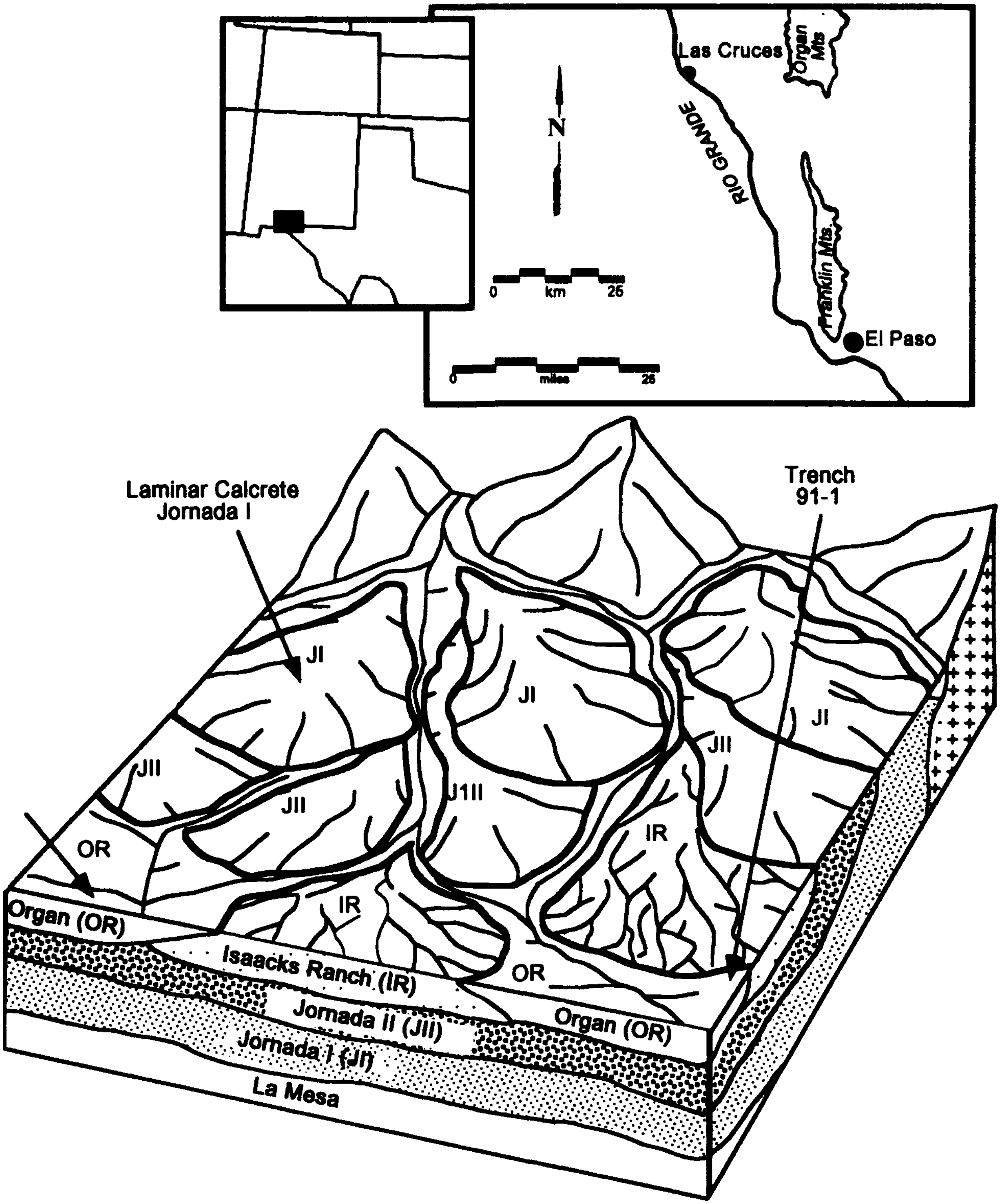


Figure VII-1. Rectangle in upper left map locates map to its right. Locations of sites in upper right map are as follows: (1) Trench 90-1, (2) Trench 91-1, (3) Laminar Calcrete Site, (4) Franklin Mountain Arroyo Site, and (5) Booker Hill Gully Site. (Lower block diagram is modified after Seager 1981, Figure 83.)

Materials and Methods

The sites are located on fan-piedmonts in the Organ and Franklin Mountains on the Fort Bliss Military Reservation in southern New Mexico (see Figure VII-1). The geomorphic setting is such that older alluvial fans occur at topographically higher elevations than younger fans (Seager 1981). Younger alluvial fans bury older fans basinwardly (see Figure VII-1). Based on stratigraphic criteria established in the neighboring USDA-SCS Desert Project (Gile and Grossman 1979; Gile et al. 1981), the fans consist of Organ, Isaacks' Ranch, Jornada II, and Jornada I alluvium. The fans were identified by their geomorphic position (Seager 1981) and soil profile development, mainly carbonate morphology (Gile et al. 1966; Gile et al. 1981:Table 7-1). The fan-piedmont deposits range in age from late Holocene to middle Pleistocene (see Table VII-1).

Table VII-1. Study Area Carbonate Morphology and Ages of Alluvial Fan Deposits (based on Gile et al. 1981; Machette 1985; Gile 1987)

Deposit	Carbonate Morphology	Age
Organ	Stage I	Holocene 0.1-7 ka
Isaacks' Ranch	Stage II	early Holocene-latest Pleistocene
Jornada II	Stage III, IV	late-middle Pleistocene 25-150 ka
Jornada I	Stage III, IV	middle Pleistocene 250-400 ka
La Mesa Geomorphic Surface	Stage IV	middle-early Pleistocene >400 ka

Trench 90-1 was excavated through Organ alluvium into Jornada II alluvium (see Figure VII-1). Trench 91-1 exposes Organ alluvium overlying Isaacks' Ranch alluvium overlying Jornada II alluvium (see Figure VII-1). The laminar calcrete site is located on a middle Pleistocene Jornada I fan (see Figure VII-1). A stable soil surface is protected by desert pavement and was chosen because it contained a stage IV petrocalcic horizon at a depth below 40 cm, the minimum depth shown by Quade et al. (1989) for carbonates to have plant-influenced isotopic signature. The Booker Hill Gully Site is located on the southeastern fan-piedmont of the Organ Mountains (see Figure VII-1). The Franklin Mountain Arroyo Site occurs approximately 8 km to the southeast of the other sites on the northern fan-piedmont of the Franklin Mountains (see Figure VII-1). This site consists of Jornada I alluvium that buries the La Mesa geomorphic surface. The La Mesa surface caps the Camp Rice fluvial facies (Seager et al. 1987), which is at least 400 ka (Gile et al. 1981; Machette 1985). Unlike the other sites, the Franklin Mountain Arroyo Site contains soils formed in limestone alluvium.

In order to test for lateral variability within a single soil horizon, samples were taken approximately 1 m apart in four of the sixteen horizons in trenches 90-1 and 91-1. Stable isotopes were analyzed by the procedure described in Chapter II.

Results and Discussion

Trench 90-1

Trench 90-1 exposes Organ alluvium over Jornada II alluvium (see Figure VII-2). Organ alluvium began to be deposited around 7 ka based on radiocarbon dates of charcoal in the Las Cruces area (Gile and Hawley 1968). The onset of Organ sedimentation may have been in response to an increase in aridity, which would have caused a decline in plant cover and an increase in erosion (Gile et al. 1981). The Jornada II alluvium is characterized by a well-developed soil that has experienced pedogenesis throughout the last glacial-pluvial period when the climate in southern New Mexico probably was wetter and cooler than the present climate (Hawley et al. 1976).

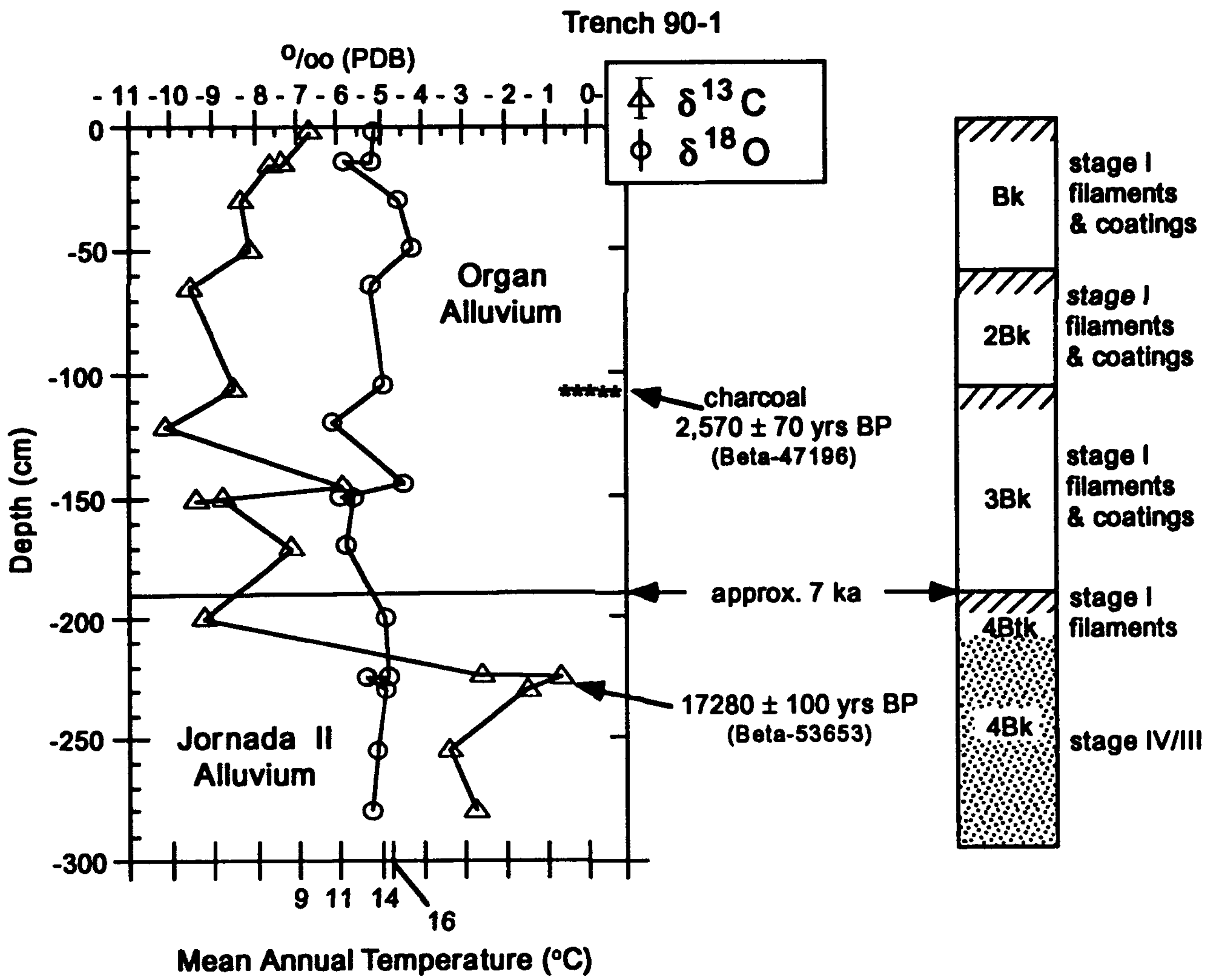


Figure VII-2. Isotopic Composition of Pedogenic Carbonate and Schematic Diagram of Trench 90-1

The $\delta^{13}C$ values range from -10 to -2.5 percent with the largest shift just prior to 7 ka (see Figure VII-2 and Table VII-2). In general, $\delta^{13}C$ values are heavier in the Pleistocene soil and lighter in the Holocene soil. This shift suggests either an influence of C-4 plants in the late Pleistocene followed by an influx of C-3 plants in the Holocene and/or a shift from low respiration rates in the late Pleistocene to higher respiration rates in the Holocene.

Presently this site is occupied by sparse desert scrub vegetation. This fact makes it unlikely that the shift toward lighter carbon was caused by an increase in soil respiration rate in the Holocene. It seems more likely that the heavier carbon in the Jornada II stage IV/III carbonates reflects a C-4-dominated grassland in the late Pleistocene. Such grasslands currently are found in scattered places in southern New Mexico and the southern High Plains to the east (Brown 1982). During the late Pleistocene wetter conditions would have caused deeper leaching and the formation of the stage IV/III calcic horizon. A change toward aridity would have caused the depth of wetting to shift upward, producing the stage I filaments in the Jornada II soil (see Figure VII-2). Soon thereafter the Organ sediments were laid down. Throughout the remaining Holocene, the lighter $\delta^{13}C$ values appear to reflect the presence of C-3 desert scrub vegetation with minor fluctuation.

The $\delta^{18}O$ ranges from -6 to -4 percent (see Figure VII-2 and Table VII-2). Hays and Grossman (1991) have related the $\delta^{18}O$ of calcite precipitated in equilibrium with meteoric water to mean annual temperature. Assuming no enrichment of $\delta^{18}O$ in the soil solution caused by evaporation, the relationship was given as $T_{inland}=17.8 \pm 16.2[-0.572 - 0.1233(\delta^{18}O_{mcl} + \delta^{18}O_{sw})]^{1/2}$, where T_{inland} is temperature in °C for temperatures of 0 to 25°C of noncoastal locations, $\delta^{18}O_{mcl}$ are values for meteoric calcite, $\delta^{18}O_{sw}$ are values for seawater, which is 0. Mean annual temperatures for corresponding $\delta^{18}O$ values are plotted on the lower horizontal axis of Figure VII-2.

There are uncertainties associated with this model. First, $\delta^{18}O$ values differ seasonally, having more negative $\delta^{18}O$ values in winter months (Yurtsever and Gat 1981). Second, isotopic enrichment caused by evaporation in the soil may affect $\delta^{18}O$ values (Schlesinger 1985; Quade et al. 1989). The uppermost sample in the Organ soil has a $\delta^{18}O$ value of -5.1 percent, which corresponds to a mean annual temperature of 14°C. Since the 1890s when mean annual temperatures were first recorded in the Las Cruces area, the mean annual temperature has remained between 14 and 16°C (Malm and Houghton 1977). If it is assumed that the uppermost horizon represents some of the most recently precipitated carbonate, then the Hays and Grossman temperature model appears to have some validity. Thus, based on this model, it appears temperatures fluctuated more in the Holocene than in the Pleistocene (see Figure VII-2). A notable cooler period occurred just prior to 2570 B.P., which was preceded by a middle Holocene warm period, possibly corresponding to Antevs' Altithermal (Antevs 1955). Soil carbonates of the Jornada II soil indicate the late Pleistocene period was approximately the same temperature as today (see Figure VII-2).

Trench 91-1

The soil stratigraphy of Trench 91-1 is similar to 90-1 except that an Isaacks' Ranch deposit occurs between the Jornada II and Organ soils (see figures VII-1 and VII-3). The $\delta^{13}C$ is similar for both trenches 90-1 and 91-1. The late Pleistocene Jornada II samples were isotopically heavy, having $\delta^{13}C$ values ranging from -1.4 and -2.2 percent (see Figure VII-3). Isaacks' Ranch alluvium contains somewhat more negative $\delta^{13}C$ values of -2.9 and -2.6 percent. A similar shift toward lighter carbon occurs in the Organ alluvium as it did in Trench 90-1 (see Figure VII-3), where $\delta^{13}C$ values are as light as -7.0 percent.

Table VII-2. Stable Isotope Values for Pedogenic Calcite on the Fort Bliss Military Reservation, Texas and New Mexico

DEPTH (cm)	HORIZON	$\delta^{13}C$	$\delta^{18}O$	CARBONATE MORPHOLOGY
Trench 90-1				
2	E	- 6.6	- 5.1	Disseminated
15*	Bk1	- 7.3	- 5.2	Stage I fil.
15*	Bk1	- 7.6	- 5.8	Stage I fil.
30	Bk1	- 8.3	- 4.5	Stage I. fil.
50	Bk2	-8.1, -8.1	-4.0, -4.4	Stage I co.
65	2Bk	- 9.5	- 5.2	Stage I fil.
105	2C	-8.4, -8.5	-4.8, -5.0	Disseminated
120	3Bk	- 10.1	- 6.1	Stage I fil.
145	3Bk	- 5.9	- 4.4	Stage I fil.
150*	4Btk	- 9.4	- 5.9	Stage I fil.
150*	4Btk	- 8.8	- 5.6	Stage I fil.
170	3C	- 7.1	- 5.8	Disseminated
200	4Btk	-9.2, -9.2	-4.9, -4.9	Stage I fil.
225	4Bkm	- 2.5	- 4.8	Stage III/IV
Beta 225	4Bkm	- 0.6	- 5.3	Stage III/IV
230	4Bkm	- 1.4	- 4.9	Stage III/IV
255	4Bkm	- 3.3	- 5.1	Stage III/IV
280	4Bk	- 2.7	- 5.2	Stage III
Trench 91-1				
+ 20	C	-6.91, -6.9	-5.42, -5.4	Disseminated
20	Bk	- 5.75	- 4.58	Stage I fil.
25	Bk	- 5.8	- 4.7	Stage I fil.
140	C'	-7 .01	-5 .68	Disseminated
180*	2Bk	-2 .9	- 5.0	Stage II nod.
180*	2Bk	- 2.9	- 5.2	Stage II nod.
Beta 180	2Bk	- 2.6	- 4.9	Stage II nod.
220*	3Btk1	- 2.2	- 5.6	Stage II nod.
220*	3Btk1	- 1.6	- 5.4	Stage II nod.
Beta 240	3Btk2	- 1.4	- 5.5	Stage III
Franklin Mountain Arroyo				
10	Bkm1	- 3.0	- 5.2	Stage IV lam.
50	Bkm3	- 6.5	- 5.0	Stave IV plu.
90	Bkm3	- 9.7	- 6.6	Stage IV plu.
140	2Btk	- 7.2	- 7.2	Stage III

Table VII-2. continued

DEPTH (cm)	HORIZON	$\delta^{13}C$	$\delta^{18}O$	CARBONATE MORPHOLOGY
Franklin Mountain Arroyo, continued				
265	2Bk2	-4.40, -4.38	-6.82, -6.89	Stage III
400	3Bkm	- 4.9	- 6.8	Stage IV lam.
425	3Btk	- 4.9	- 7.1	Stage III
445	3Bk	- 5.4	- 6.8	Stage III
Booker Hill Gully				
5	C	- 9.1	- 6.3	Disseminated
40	Btk1	- 7.8	- 5.3	Stage I
60	Btk2	- 7.5	- 5.1	Stage I
80	2Btk1	- 7.1	- 5.3	Stage I/II
110	2Btk2	- 1.2	- 5.3	Stage III
140	3Btk1	- 1.9	- 5.9	Stage III
215	3Bk	- 3.4	- 6.1	Stage III

*Samples taken approximately 1 m apart in same horizon to determine lateral variability.

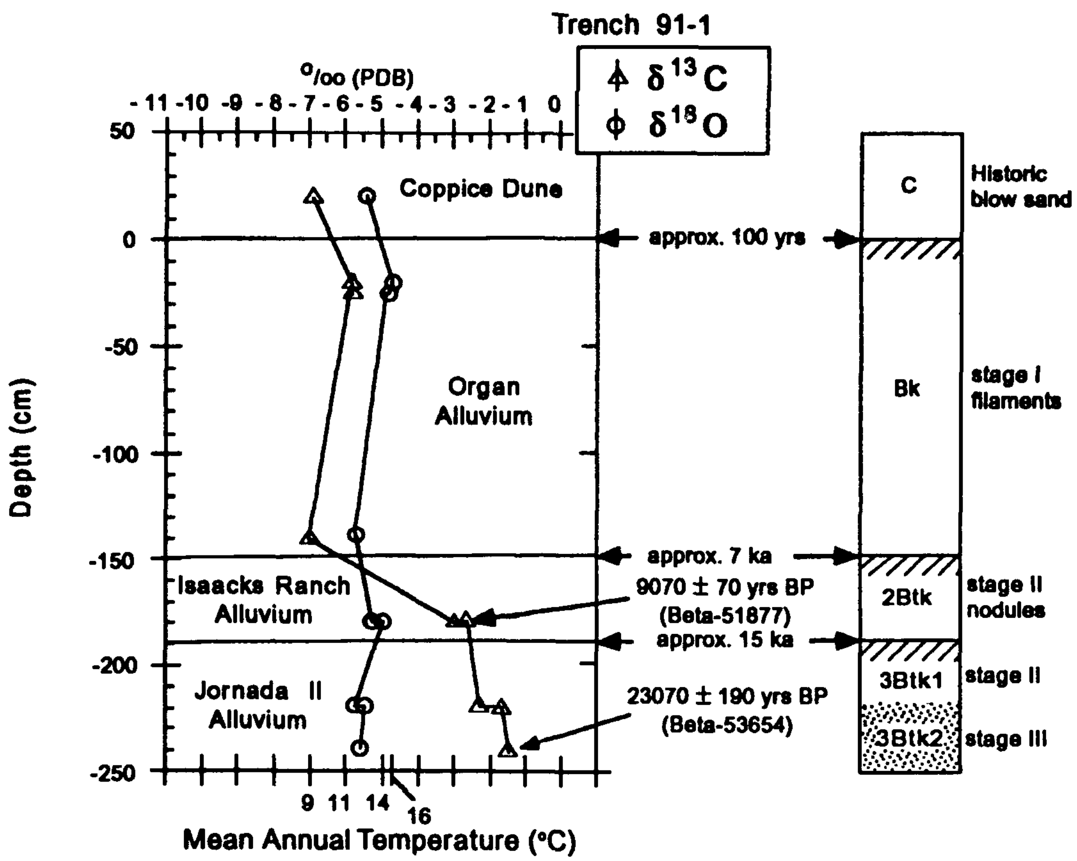


Figure VII-3. Isotopic Composition of Pedogenic Carbonates and Schematic Diagram of Trench 91-1

The Organ soil is overlain by coppice dune material associated with mesquite vegetation. These dunes appear to have formed in the last 100 years as the result of desertification and wind erosion of soils (Dick-Peddie 1975; Gile 1966). Because of their young age, they have the potential of providing information on carbonate isotopic composition precipitated since the late 1800s. The isotopic signal may not fully represent historic times because thin sections reveal some of the carbonate in the dunes is detrital, probably originating from older soils upwind. However, the $\delta^{13}C$ value (-6.9 percent) is similar to other late Holocene carbonates in Trench 90-1.

The coppice dune sample has a $\delta^{18}O$ value of -5.4 percent, indicating a mean annual temperature of 12.8°C based on the model by Hays and Grossman (1991). This value is only slightly below the 14° to 16°C measured values for the last 100 years (Malm and Houghton 1977). As with Trench 90-1, the $\delta^{18}O$ values, which range from -5.7 to -4.6 percent, fluctuate much less than $\delta^{13}C$ values (see Figure VII-3 and Table VII-2). The constancy of $\delta^{18}O$ values again implies that Holocene and late Pleistocene temperatures were similar.

Laminar Calcrete Site

Multiple laminar layers, each a few millimeters thick, have formed atop petrocalcic horizons in many of the mid-Pleistocene soils. Because the calcite content is greater than 50 percent, there is ample inorganic carbon for radiocarbon dating. These dates, however, must be used with caution because inorganic C-14 dates have, in some cases, given dates a few thousand years older than C-14 dates of organic material taken from the same horizon (Williams and Polach 1971; Gile and Grossman 1979). Nevertheless, laminar calcrete is potentially useful because it provides the most continuous and highest resolution record of pedogenic carbonate found in the Fort Bliss area.

The laminar layers contain isotopically heavy $\delta^{13}C$ values that are consistent with late Pleistocene carbonates of trenches 90-1 and 91-1 (see Figure VII-4) and probably signal the presence of a C-4-dominated grassland. Laminar layer A, which has a similar date of around 9 ka to stage II nodules in the Isaacks' Ranch soil of Trench 91-1, also has a similar $\delta^{18}O$ value: -4.5 percent compared to -4.9 percent in Trench 91-1. The $\delta^{18}O$ values imply cooler temperatures around 16 ka (see Figure VII-4), which would have been relatively soon after the last glacial maximum that occurred 18 to 22 ka (Bull 1991). Laminar C Horizon suggests somewhat warmer conditions around 30.5 ka (see Figure VII-4).

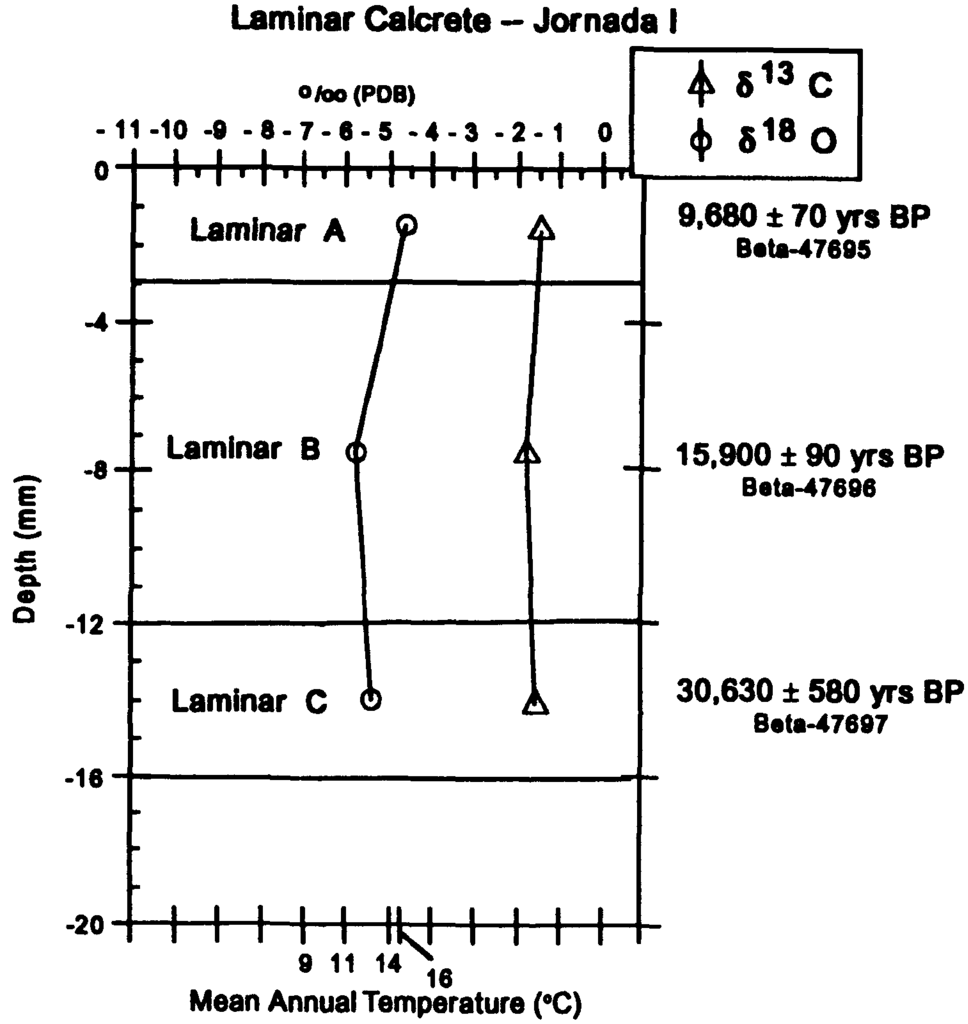


Figure VII-4. Isotopic Composition and Inorganic Radiocarbon Dates of Pedogenic Carbonates at the Laminar Calcrete Site

Franklin Mountain Arroyo

The Franklin Mountain Arroyo Site extends the isotopic record back though the late Pleistocene into the middle-early Pleistocene. The upper portion of this sequence contains a Jornada I petrocalcic horizon (see Figure VII-5). The uppermost sample is of Jornada I laminar calcrete that is late Pleistocene in age based on comparison with similar laminar material at the Laminar Calcrete Site in this study and in the Desert Project (Gile et al. 1981). Similar to the other late Pleistocene carbonate, this laminar material has isotopically heavy $\delta^{13}C$ (see Figure VII-5). Prior to late Pleistocene time, $\delta^{13}C$ values are more negative, possibly signifying a

previous interglacial period with arid conditions and C-3 desert scrub similar to today. In the buried La Mesa soil, $\delta^{13}C$ values swing back to intermediate values of -5 percent.

The $\delta^{18}O$ values in the late Pleistocene carbonates of this site are around -5 percent, consistent with other sites and again implying temperatures similar to today. Cooler temperatures, however, are indicated for earlier periods (see Figure VII-5). Measurements of paleosol carbonates elsewhere in southern New Mexico indicate cooler temperatures during the Plio-Pleistocene (Dr. Greg Mack 1992, personal communication).

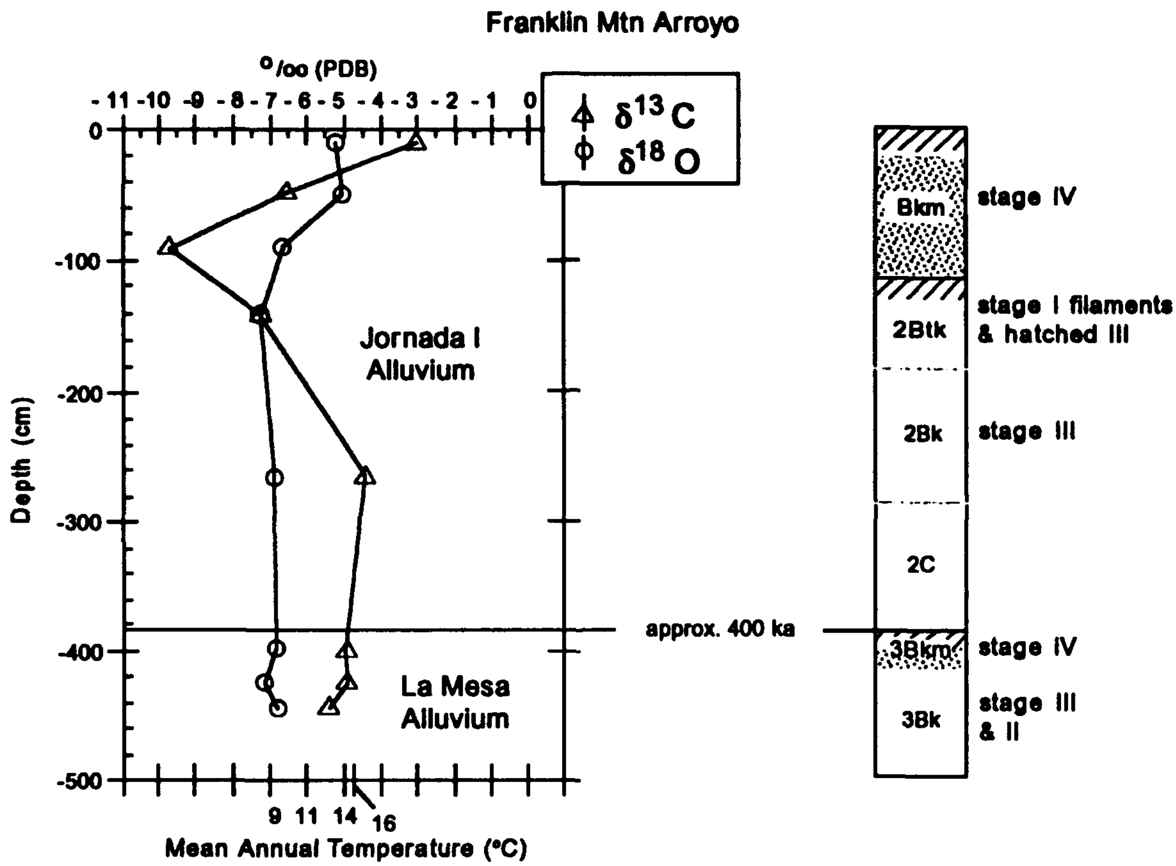


Figure VII-5. Isotopic Composition of Pedogenic Carbonates and Schematic Diagram of the Franklin Mountain Arroyo Site

Booker Hill Gully

The Booker Hill Gully site contains Historical blowsand material overlying Organ, Jornada II, and Jornada I alluvium (see Figure VII-6). The Booker Hill Gully has three radiocarbon dates: a hearth and two pedogenic carbonate samples (see Figure VII-6). The Booker Hill Gully site contains the same isotopic signature as trenches 90-1 and 91-1: isotopically heavy carbon in the Pleistocene that shifts to lighter carbon in the Holocene, and $\delta^{18}O$ values that change little across the Pleistocene-Holocene boundary.

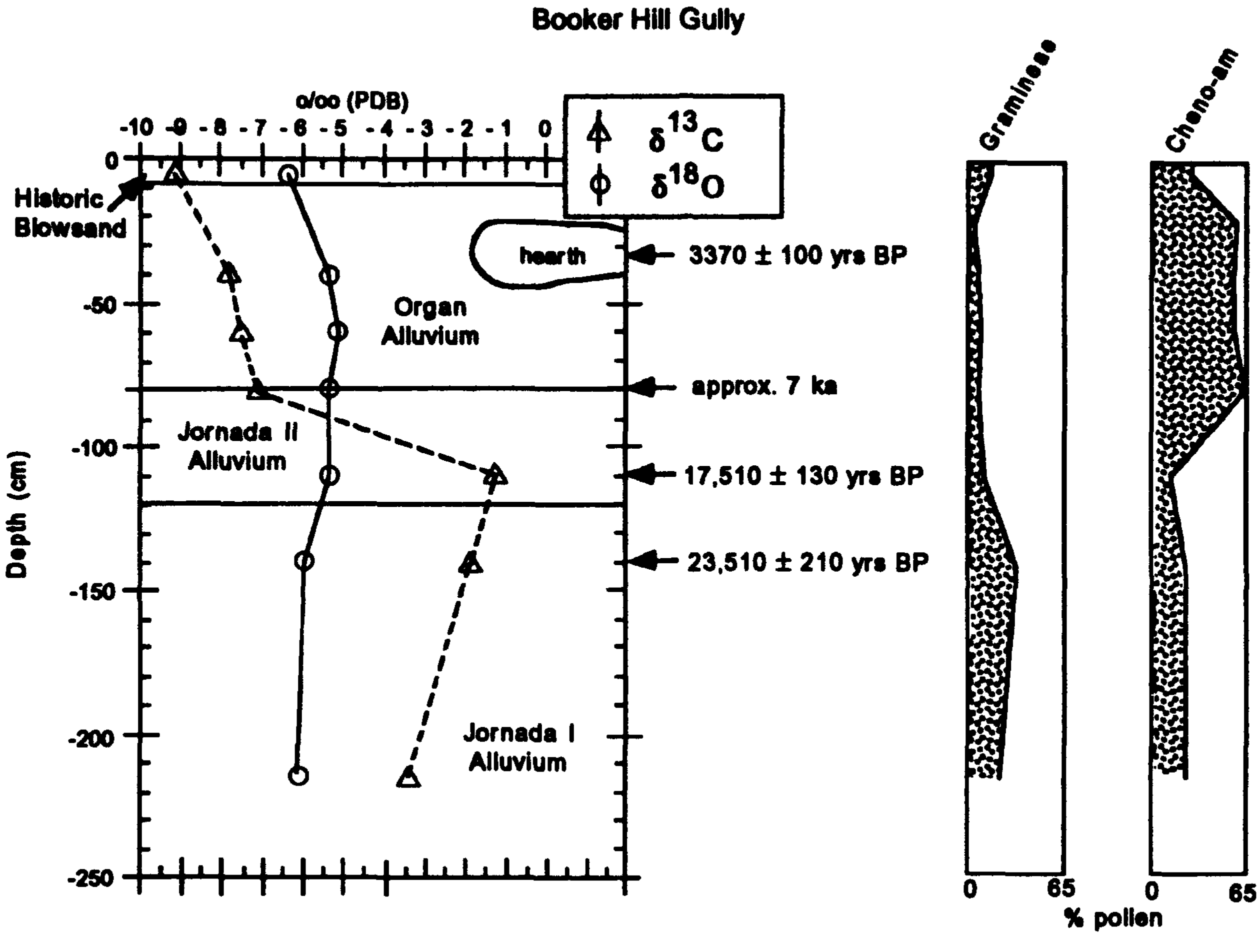


Figure VII-6. Stable Isotopic Signatures and Pollen Content in Soil Strata at the Booker Hill Gully Site

Pollen also was analyzed at the Booker Hill Gully site (see Chapter IX). Figure VII-6 illustrates the amount of Gramineae and Cheno-am pollen contained in the soil strata. Most of the modern grasses in southern New Mexico are warm-season grasses with C-4 photosynthetic pathways (John Anderson, NMSU Biology Department, personal communication). Pollen analysis cannot distinguish between various grass species; however, we assume that the fossil pollen represents C-4 grasses. If this assumption is correct, the pollen record, which suggests a decline in grass abundance in the early Holocene, supports the interpretation that the shift in $\delta^{13}C$ toward lighter values was caused by the decline in grassland.

Cheno-am plants generally have C-4 photosynthetic pathways that produce isotopically heavy carbon. Their presence, however, appears to be good indicator of C-3-dominated desert scrub vegetation (Gish:Chapter 9). The modern desert scrub community in the study area is dominated by C-3 plants. Thus, if the increase in Cheno-am pollen in the Holocene (see Figure VII-6) signifies the domination of C-3 plants, then the soil carbonates of Holocene age should contain lighter carbon, which is the case (see Figure VII-6).

Summary

The most striking isotopic pattern revealed by this study is the shift from heavy to light $\delta^{13}C$ values in the early Holocene. Figure VII-7 illustrates the shift that occurred around 8 ka. Percent C-4 biomass based on Cerling 1984 is also plotted on the graph. We interpret the $\delta^{13}C$ to reflect the change from a C-4 grassland to a C-3 desert scrub environment. Van Devender (1990), in his packrat midden studies in the Hueco Mountains of Fort Bliss, also shows vegetational changes at 8 ka.

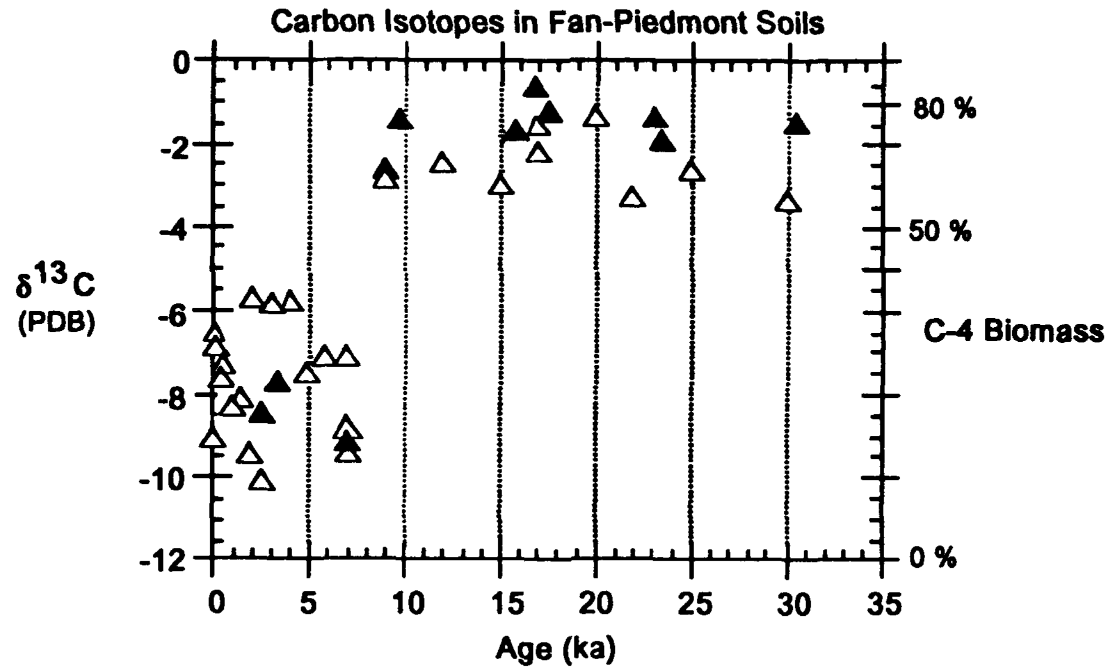


Figure VII-7. $\delta^{13}C$ Values Versus Time for Study Sites: Trench 90-1, 91-1, and Booker Hill Gully (Solid triangles are samples with radiocarbon dates.)

The $\delta^{18}O$ values, which are inherited from meteoric waters, change little across the Pleistocene-Holocene boundary (see Figure VII-8). Because $\delta^{18}O$ values in soil carbonates are inherited from rainwater, they potentially contain information about paleotemperatures since the concentration of $\delta^{18}O$ in precipitation is a function of mean annual temperature. If $\delta^{18}O$ in soil carbonates do indicate paleotemperatures, then Holocene and late Pleistocene temperatures were similar.

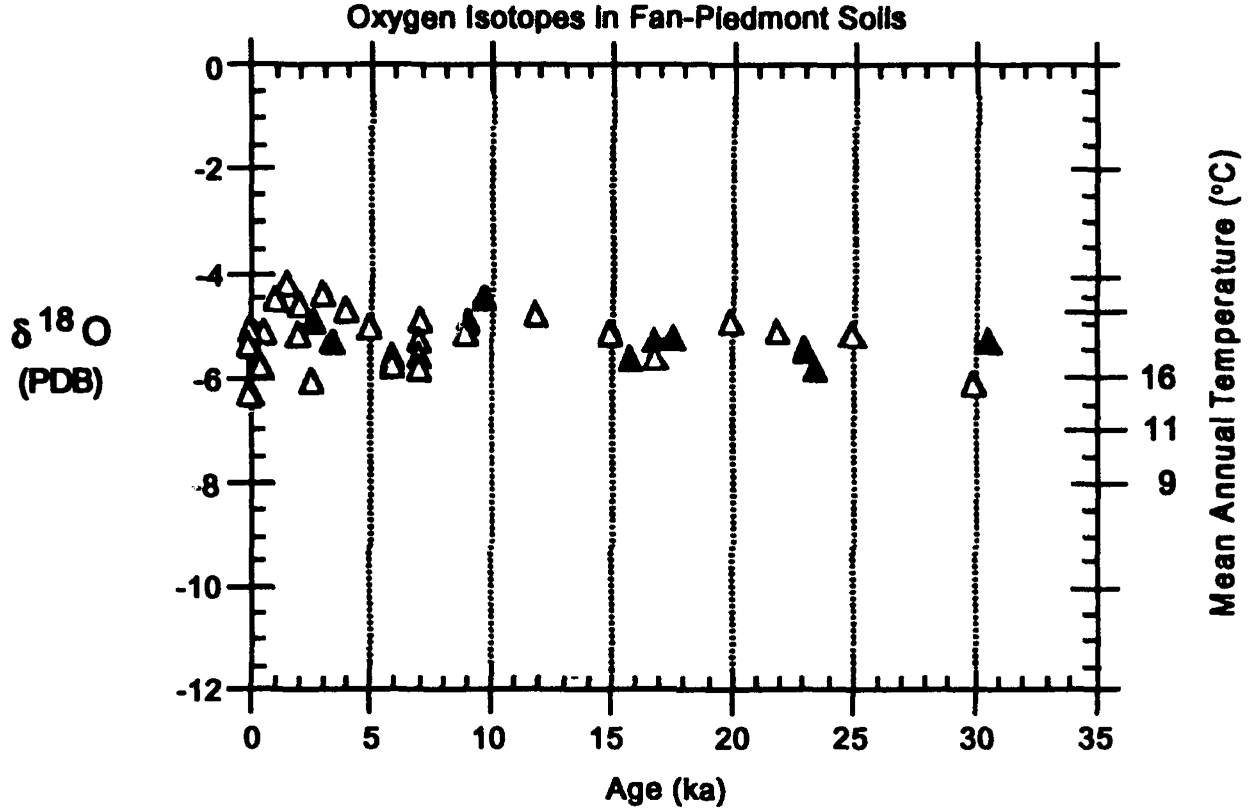


Figure VII-8. $\delta^{18}O$ Values Versus Time for Study Sites: Trench 90-1, 91-1, and Booker Hill Gully (Solid triangles are samples with radiocarbon dates.)

Chapter VIII

RADIOCARBON AND STABLE ISOTOPES IN THE BASIN FLOOR SOILS ON FORT BLISS

By H. Curtis Monger

Radiocarbon dates of pedogenic carbonate were measured for 28 soil samples on Fort Bliss; most were from soils of the basin floor (see Table VIII-1). The dates are arranged chronologically and range from 3070 to 30,630 B.P. Filaments are the youngest form of pedogenic carbonate, followed by nodules, and the plugged portions of petrocalcic horizons. Laminar layers covered a wide range of time (see Table VIII-2). One carbonate sample from an insect cast in the Tobin Well area was also analyzed and gave a date of 8590 ±140 B.P.

Table VIII-1. C-14-dated Inorganic Carbon and Stable Isotopes (vs. PDB) Arranged Chronologically

SAMPLE	UTM LOCATION	C-13 ADJUSTED AGE (yrs. BP)	$\delta^{13}C$	$\delta^{18}O$	CARBONATE MORPHOLOGY
1X1 Organ II (Beta-54924)	855296	3070 ±200	- 3.8	- 2.6	Filaments
1X1 Organ I (Beta-54923)	855296	4170 ±200	- 3.2	- 0.6	Filaments
Tobin Well OrII (Beta-55380)	704274	5380 ±60	- 4.1	- 5.7	Filaments
Tr 7b Nodules (Beta-51883)	855295	7080 ±100	- 4.2	- 5.3	Incipient Nodules
Tr5 Laminar A (Beta-51878)	881302	7700 ±60	- 4.6	- 4.9	Laminar
OCL Ck1 (Beta-55376)	667625	8220 ±120	- 3.0	- 5.9	Powdery Nodules
Tobin Well OrIII (Beta-55379)	704274	8590 ±140	- 4.3	- 6.2	Insect Casts
Tr 91-1 Nodules (Beta-51877)	641634	9070 ±70	- 2.6	- 4.9	Nodules
J1 Laminar A (Beta-47695)	601572	9680 ±70	- 1.4	- 4.5	Laminar
Tr16 (Beta-53652)	863284	9930 ±70	- 2.7	- 3.5	Lag Nodules
Army Trench (Beta-53651)	767299	9930 ±70	- 2.1	- 4.4	Lag Nodules
Tr 7b Lag Nodules (Beta-54925)	855295	11,320 ±70	- 3.0	- 4.8	Lag Nodules
OCL 2Btk2 (Beta-55377)	667625	12,260 ±130	- 3.3	- 6.6	Nodules
SAK-1 (Beta-53190)	32835	14,360 ±120	- 0.9	- 5.1	Plugged
J1 Laminar B (Beta-47696)	601572	15,900 ±90	- 1.7	- 5.7	Laminar
Tr5 laminar B (Beta-51879)	881302	15,910 ±90	- 5.0	- 7.6	Laminar
Tr90-1 225cm (Beta-53653)	559574	17,280 ±100	- 0.6	- 5.3	Plugged
BHG-110 (Beta-55374)	530508	17,510 ±130	- 1.2	- 5.3	Plugged
Tr 7b Laminar (Beta-51882)	855295	18,460 ±100	- 3.8	- 7.0	Laminar
1X1 Laminar (Beta-54922)	855296	21,900 ±190	- 4.2	- 6.2	Laminar
Tr 91-1 240 cm (Beta-53654)	641634	23,070 ±190	- 1.4	- 5.5	Plugged
SAK-3 (Beta-53192)	43833	23,140 ±170	- 3.7	- 7.1	Plugged
Tr5 Laminar C (Beta-51880)	881302	23,440 ±200	- 4.2	- 7.4	Laminar
BHG-140 (Beta-55375)	530580	23,510 ±210	- 1.9	- 5.9	Plugged

Table VIII-1. continued

SAMPLE	UTM LOCATION	C-13 ADJUSTED AGE (yrs. BP)	$\delta^{13}C$	$\delta^{18}O$	CARBONATE MORPHOLOGY
SAK-2 (Beta-53191)	17834	26,650 ±600	- 3.9	- 6.0	Stage IV Plugged
OCL 2Btk4 (Beta-55378)	667625	26,780 ±310	- 1.7	- 5.4	Plugged
Tr5 Laminar D (Beta-51881)	881302	26,870 ±260	- 3.2	- 6.7	Laminar
J1 Laminar C (Beta-47697)	601572	30,630 ±580	- 1.5	- 5.4	Laminar

Table VIII-2. Radiocarbon Ages and Corresponding Morphology of Soil Carbonate Samples

	AGE	MORPHOLOGY
1	3070.0	Filaments
2	4170.0	Filaments
3	5380.0	Filaments
4	7080.0	Nodules
5	7700.0	Laminar
6	8220.0	Nodules
7	8590.0	Insect Cast
8	9070.0	Nodules
9	9680.0	Laminar
10	9930.0	Nodules
11	9930.0	Nodules
12	11,320	Nodules
13	12,260	Nodules
14	14,360	Plugged
15	15,900	Laminar
16	15,910	Laminar
17	17,280	Plugged
18	17,510	Plugged
19	18,460	Laminar
20	21,900	Laminar
21	23,070	Plugged
22	23,140	Plugged
23	23,440	Laminar
24	23,510	Plugged
25	26,650	Plugged
26	26,780	Plugged
27	26,870	Laminar
28	30,630	Laminar

Figure VIII-1 compares age and the change in $\delta^{13}C$ and $\delta^{18}O$ values for all radiocarbon samples. Unlike the fan-piedmont values (see Chapter VII), the compilation of all radiocarbon-dated samples, most of which are basin floor samples, shows a lot of variability. The variability probably is the result of carbonate dust contamination. In the basin floor where older soil carbonates have been exhumed, particles from the older carbonates blow around and can be incorporated with authigenic soil carbonates.

Keeping in mind the possibility of dust contamination, two trends might be reflected in the stable isotope data (see Figure VIII-1). First, the $\delta^{13}C$ values, although fluctuating greatly in late Pleistocene time, show a shift toward lower values around 8 ka, as did the piedmont soils (see Chapter VII). Second, the $\delta^{18}O$ values show a trend toward greater values in younger samples. Although this trend did not occur in the fan-piedmont soils, if the trend is real it would indicate warming temperatures or a change to summer precipitation in the latest Pleistocene and Holocene.

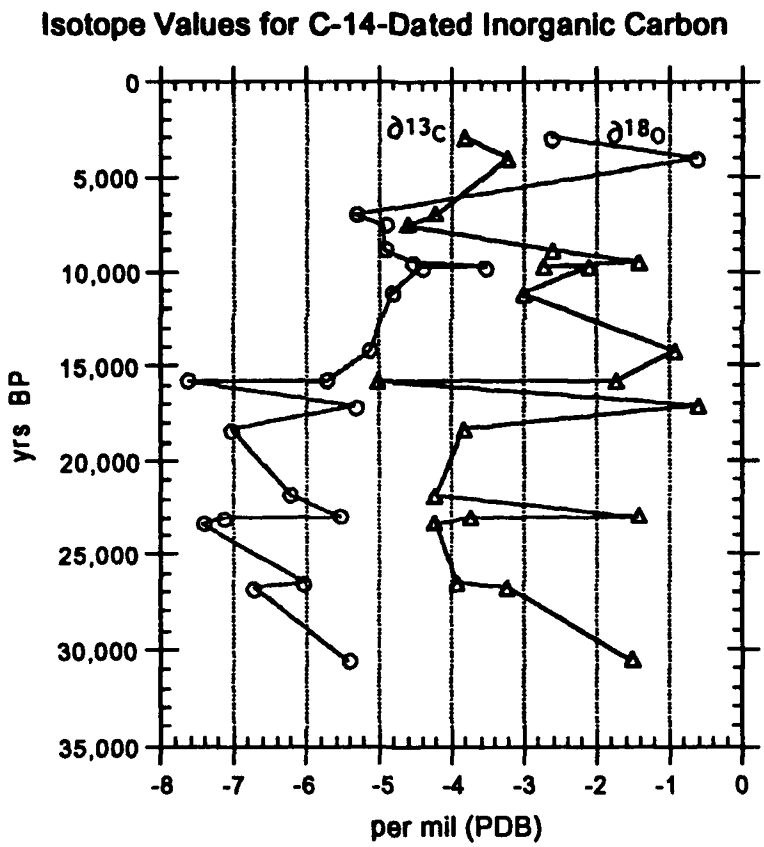


Figure VIII-1. Stable Carbon and Oxygen Isotopes Plotted Against Time

The Old Coe Lake Gully Site (see Figure I-2) contains coppice dune deposits overlying Lake Tank and Petts Tank alluvium (see Figure VIII-2). This site is somewhat similar to the fan-piedmont sites. The $\delta^{18}O$

values are around -5 percent and change little throughout the late Pleistocene and Holocene (see Figure VIII-2). In addition, the $\delta^{13}C$ values shift toward lighter values after 8220 B.P., which is approximately the time $\delta^{13}C$ values shift in the fan-piedmont soil. However, the $\delta^{13}C$ values in Old Coe Lake are not as heavy and the shift is not as great as in the fan-piedmont soils.

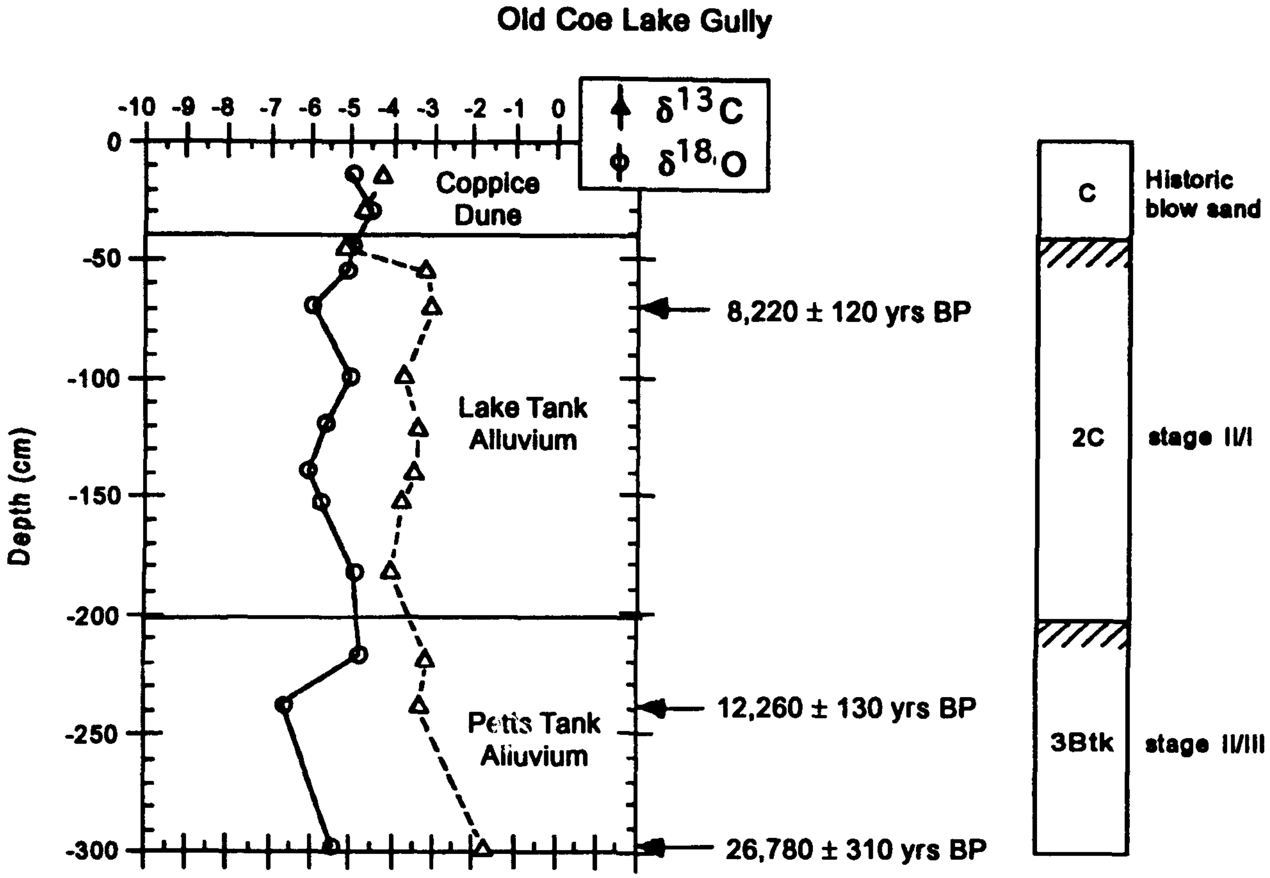


Figure VIII-2. Isotopic Composition of Pedogenic Carbonate and Schematic Diagram of the Old Coe Lake Gully Site

Chapter IX

POLLEN RESULTS FROM THREE STUDY LOCALITIES ON THE FORT BLISS MILITARY RESERVATION, NEW MEXICO

By Jannifer W. Gish

Introduction

Forty-eight pollen samples from several study localities on the Fort Bliss Military Reservation in southern New Mexico were evaluated. All were studied in conjunction with geomorphological research on Pleistocene/Holocene stratigraphic sequences. Fifteen pollen samples from Old Coe Lake Gully (OCL), nine from Booker Hill Gully (BHG), ten from Franklin Mountain Arroyo (FMA), and five from Ray's Fault Trench (RFTr) were analyzed (see Table IX-1). Nine other samples from test study localities also were evaluated (see Table IX-1). The main objectives of the pollen study were to investigate pollen preservation at the various study localities, to formulate vegetation reconstructions for the three main study sites, and to determine if the pollen-based vegetation reconstructions showed major contrasts across the Pleistocene/Holocene boundary.

Table IX-1. Pollen Sample Proveniences for Fort Bliss

KEY: IP = Insufficient Pollen

LOCATION	POLLEN SAMPLE	AGE (ka)	DEPOSIT	HORIZON DEPTH (cm) BELOW SURFACE	SAMPLE DEPTH (cm) BELOW SURFACE	SOIL/SEDIMENT	MEAN POLLEN CONCENTRATION PER ml OF SOIL
Old Coe Lake Gully (OCL)							
Coppice Dune	Surface	Recent	Coppice Dune	0-2	0-1	Control Sample	37667
Coppice Dune	C1	Historic	Coppice Dune	0-20	15	?	75333
Coppice Dune	C2	Historic	Coppice Dune	20-40	30	?	25111
Lake Tank Late	E	0.1-7	Basin Floor	40-47	45	?	75333
Lake Tank Late	Btk	0.1-7	Basin Floor	47-60	55	?	75333
Lake Tank Late	Ck1	0.1-7	Basin Floor	60-93	70	?	75333
Lake Tank Late	Ck2	0.1-7	Basin Floor	93-113	100	?	37667
Lake Tank Late	Ck3	0.1-7	Basin Floor	113-130	120	?	15067
Lake Tank Late	Ck4	0.1-7	Basin Floor	130-148	140	?	37667
Lake Tank Early	E'	8-15	Basin Floor	148-156	153	?	37667
Lake Tank Early	B'tk	8-15	Basin Floor	156-203	183	?	75333
Petts Tank	2Btk1	25-75	Basin Floor	203-228	218	?	12556
Petts Tank	2Btk2	25-75	Basin Floor	228-253	238	?	12556

Table IX-1, continued

LOCATION	POLLEN SAMPLE	AGE (ka)	DEPOSIT	HORIZON DEPTH (cm) BELOW SURFACE	SAMPLE DEPTH (cm) BELOW SURFACE	SOIL/SEDIMENT	MEAN POLLEN CONCENTRATION PER ml OF SOIL
Old Coe Lake Gully (OCL), continued							
Petts Tank	2Btk3	25-75	Basin Floor	253-288	263	Calcareous	IP
Petts Tank	2Btk4	25-75	Basin Floor	288-303+	298	?	IP
Booker Hill Gully (BHG)							
Coppice Dune	C	Historic	Coppice Dune	0-5	5	Sandy-Clay	37667
Organ	Btk1	3.4	Alluvial Fan	5-50	(?) 30	Hearth Fill	12556
Organ	Btk1	About 4	Alluvial Fan	5-50	40	Sandy-Clay	6278
Organ	Btk2	About 4	Alluvial Fan	50-65	60	Sandy-Clay	37667
Jornada II	2Btk1	25-125	Alluvial Fan	65-92	80	Sandy-Silt	9417
Jornada II	2Btk2	25-125	Alluvial Fan	92-120	110	Calcareous SaCl	267
Jornada I	3Btk1	250-400	Alluvial Fan	120-170	140	Calcareous SaCl	1345
Jornada I	3Btk2	250-400	Alluvial Fan	170-205	190	Calcareous SaCl	IP
Jornada I	3Bk	250-400	Alluvial Fan	205-220+	215	Sandy-Clay	113
Franklin Mountain Arroyo (FMA)							
Jornada Ib	A		Alluvial Fan	0-5	2	Calcareous	37667
Jornada Ib	Bk	250-400	Alluvial Fan	5-10	7	?	6848
Jornada Ib	Bkm3	250-400	Alluvial Fan	90-115	105	?	33
Jornada Ia	2Btk	250-400	Alluvial Fan	115-185	145	?	IP
Jornada Ia	2Bk1	250-400	Alluvial Fan	185-235	195	?	IP
Jornada Ia	2Bk2	250-400	Alluvial Fan	235-285	265	?	IP
Jornada Ia	2C	250-400	Alluvial Fan	285-385	365	?	IP
La Mesa	3Bkm	400-1500	Alluvial Fan	385-415	395	Calcareous	IP
La Mesa	3Btk	400-1500	Alluvial Fan	415-435	425	?	IP
La Mesa	3Bk	400-1500	Alluvial Fan	435-475+	460	?	IP
Ray's Fault Trench (RFTr)							
Fault Trench	Surface	Modern	Coppice Dune	0-5	?	?	5381
Organ II	33 cm	1.1-2.1	Eolian Dune	?	33	?	199
Organ II	85 cm	1.1-2.1	Eolian Dune	?	85	?	IP
Organ II	110 cm	2.1	Eolian Dune	?	110	?	IP
Organ I	150 cm	2.1-7.0	Eolian Dune	?	150	?	IP
Test Loci							
90-1	Surface	Modern	Alluvial Fan	0-5	?	Control Sample	12556

Table IX-1, continued

LOCATION	POLLEN SAMPLE	AGE (ka)	DEPOSIT	HORIZON DEPTH (cm) BELOW SURFACE	SAMPLE DEPTH (cm) BELOW SURFACE	SOIL/SEDIMENT	MEAN POLLEN CONCENTRATION PER ml OF SOIL
Test Loci, continued							
Organ I/II	1	2.5	Alluvial Fan	?	?	Charcoal Layer	6848
Jornada II	2	25	Alluvial Fan	255-265	260	?	401
Profile 2	3	?	Lake Shoreline	250-260	250-260	Sand	167
Profile 3	4	?	Eolian	?	270	Sand	IP
Trench 16							
Organ III	Tench 648	?	?	?	?	Calcareous Nodule	IP
Organ III	Army Trench	?	?	?	?	Calcareous Nodule	IP
SAK							
SAK	SAK1	?	?	?	?	?	294
SAK	SAK3	?	?	?	?	?	IP

Methods and Data Presentation

All samples were processed chemically by the Texas A&M University Palynology Laboratory. Because of the low organic content of many of the samples, 60-ml-sample volumes generally were processed. Exceptions were the SAK, Trench 16 (Army Trench and Trench 648), and Ray's Fault Trench samples (a total of nine samples) where only 20-ml-sample volumes were processed. Standard treatments with hydrochloric and hydrofluoric acid and heavy liquid flotation with a zinc bromide solution comprised the major processing steps. Two *Lycopodium* tracer spore tablets were added to each sample during processing in order to calculate mean pollen concentrations per ml of sediment/soil (see Table IX-1). The formula used was mean number of spores per tablet (11,300 ±400) x number of pollen counted (100 or 200 grains)/number of spores recorded during the count x sample volume size (60 ml or 20 ml).

A moderately large diversity of pollen taxa was recorded (see Table IX-2). Botanical nomenclature follows Lehr (1978); palynological nomenclature follows standard usage. Pollen identifications were made at 400X magnification. The 100- or 200-grain counts are of combined arboreal pollen (AP) and nonarboreal pollen (NAP). The spectrum of represented categories includes local, regional, and extra-regional taxa, diagnostic riparian indicators, and diagnostic historic indicators. These are discussed in greater detail later in the specific study locality interpretations.

Table IX-2. Scientific and Common Botanical and Palynological Names

SCIENTIFIC NAME	COMMON NAME
Arboreal Taxa	
Carya	Pecan
Juglans	Walnut
Juniperus	Juniper
Picea	Spruce
Pinus	Pine Fragments/3
Pinus edulis-type	Pinyon-type Pine
P. ponderosa-type	Ponderosa-type Pine
Prosopis	Mesquite
pseudotsuga	Douglas Fir
Quercus	Oak
Salix	Willow
Ulmus	Elm
Nonarboreal Taxa	
Acacia	Acacia
Artemisia	Sagebrush
Boerhaavia-type	Spiderling-type
Calandrinia	Red Maids
Caryophyllaceae	Pink Family
Cheno-am	Chenopodiaceae (Goosefoot Family) and *Amaranthus* (Amaranth)
Cruciferae	Mustard Family
Cylindropuntia	cholla
Dithyrea-type	Spectacle-pod-type
Ephedra nevadensis-type	Joint-fir
E. torreyana-type	Joint-fir
Eriogonum	Wild Buckwheat
Euphorbia-type	Spurge-type
Gilia-type	Gilia-type
Gramineae	Grass Family
High-spine Compositae	Compositae Group, including *Helianthus* (Sunflower)
Kalistroemia-type	Kalistroemia-type
Labiatae	Mint Family
Larrea	Creosotebush
Lg. Gramineae	Grass Grains more than 45 microns in diameter

Table IX-2, continued

SCIENTIFIC NAME	COMMON NAME
Nonarboreal Taxa, continued	
Low-spine Compositae	Compositae Group, including *Ambrosia* (Bursage)
Mirabilis-type	Four-o'clock-type
Oenothera-type	Evening-primrose-type
Papilionoideae	Subfamily of the Leguminosae
Physalis/Solanum	Groundcherry/Nightshade
Plantago	Plantain
Platyopuntia	Prickly Pear
Polygonum	Smartweed
Portulaca	Purslane
Rhamnaceae	Buck-thorn Family
Sphaeralcea-type	Globe-mallow-type
Tidestromia-type	Tidestromia-type

Pollen results are expressed as percentages in the base data tables (see tables IX-3 through IX-6). In addition to counts, each slide was scanned at 100X magnification to identify more taxa that might have an ecological significance. Taxa observed in scanning are marked by an "X" on the base data tables. Pollen aggregates also were recorded systematically. Aggregates are clumps of the same pollen type that generally are diagnostic of short distance pollen dispersal and thus local or regional plant presence. A designation such as "Ch-30b" means that up to five (b) aggregates of Cheno-am pollen were observed during the count and the largest contained an estimated 30 grains. The letter "a" stands for one aggregate, "b" for up to five, "c" for up to ten, and so on (see bottom of raw data tables for explanation). Aggregates of 20 grains or less are counted individually. Larger masses of grains are rounded off to the nearest multiple of five or ten, with very large aggregates being rougher estimates. Aggregates observed in scanning are recorded in parentheses. When this occurs, only the largest aggregate of the taxon observed during scanning is recorded. The significance of aggregates differs by the taxon under consideration (anemophilous versus entomophilous, arboreal versus herbaceous taxon, and so on), and this is discussed in the interpretation of each study locality as needed.

Pollen Results

Each study locality first is described in terms of its modern setting (elevation, topography, and modern vegetation). Stratigraphic characteristics are then discussed, followed by a description and interpretation of the pollen results.

Old Coe Lake Gully

The Old Coe Lake Gully sequence is from the cut bank of an arroyo feeding north into Old Coe Lake playa. The study site is in basin floor sediments east of the Organ Mountains. Topography essentially is flat

and elevation is about 4,000 ft (1,219 m). A saltbush/mesquite (*Atriplex canescens/Prosopis* sp.) community dominates in the surrounding environs. Associated plants (down in the arroyo and on the adjacent flat) include snakeweed (*Gutierrezia* sp.), creosotebush (*Larrea* sp.), joint-fir (*Ephedra* sp.), cocklebur (*Xanthium* sp.), jimson weed (*Datura* sp.), globemallow (*Sphaeralcea* sp.), spurge (*Euphorbia* sp.), mustards, herbaceous composites, and grasses.

The upper approximately 1.5 m of Old Coe Lake sequence is mostly Holocene in age; maximum studied depth (3.0+ m) dates back as far as 25-75 ka. The basin floor alluvial deposits are topped by shrub coppice dunes.

Table IX-3. Pollen Results from Old Coe Lake Gully

KEY:
LT = Lake Tank — Ch = Cheno-am — Gr = Gramineae — Lo = Low-spine Compositae
Ar = *Artemisia* — Cr = — Hi = High-spine Compositae

DEPOSIT:	DUNE	DUNE	DUNE	LT LATE	LT LATE	LT LATE	LT LATE
HORIZON:		C1	C2	E	B'tk	Ck1	Ck2
CONTEXT:	SURFACE CONTROL	DUNE	DUNE	ALLUVIAL FAN	ALLUVIAL FAN	ALLUVIAL FAN	ALLUVIAL FAN
DEPTH (cm):	0-1	15	30	45	55	70	100
Arboreal Pollen							
Pinus edulis-type	3.0	3.5	2.5	5.0	0.5	1.0	0.5
P. ponderosa-type	1.0	1.0		1.0	X	X	
Pinus		0.5	0.5	0.5			
Juniperus	2.5		3.0	3.0	1.0	1.0	1.0
Quercus	1.0	0.5	1.0	1.0			
Prosopis		1.0	0.5				
Carya	X	0.5					
Nonarboreal Pollen							
Low-spine Compositae	19.5	19.0	13.0	17.5	29.5	25.5	36.0
High-spine Compositae	14.0	12.0	12.0	5.0	11.5	6.5	9.0
Artemisia	1.5	0.5	2.0	2.5	0.5	1.0	2.5
Liguliflorae					0.5		
Cheno-am	36.5	45.5	46.0	27.0	41.0	47.5	34.0
Tidestromia-type	0.5	0.5	0.5	1.5			
Graminae	14.5	6.5	9.0	22.0	10.5	10.5	10.0
Caryophyllaceae		1.0					
Dithyrea-type							0.5
Cruciferae	0.5	1.0	0.5	0.5			
Ephedra nevadensis-type	X						

Table IX-3, continued

DEPOSIT:	**DUNE**	**DUNE**	**DUNE**	**LT LATE**	**LT LATE**	**LT LATE**	**LT LATE**
HORIZON:		**C1**	**C2**	**E**	**B'tk**	**Ck1**	**Ck2**
CONTEXT:	**SURFACE CONTROL**	**DUNE**	**DUNE**	**ALLUVIAL FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**
DEPTH (cm):	**0-1**	**15**	**30**	**45**	**55**	**70**	**100**
Nonarboreal Pollen, continued							
E. torreyana-type	0.5	X		X		2.0	
Euphorbia-type			2.5	0.5			0.5
Labiatae		0.5					
Sphaeralcea-type	X			X			X
Boerhaavia-type		0.5		X	0.5	0.5	X
Mirabilis-type		X					
Oenothera-type		X					
Plantago	1.0	0.5	1		0.5		
Eriogonum		0.5		9.0			
Kallstroemia-type						X	
Larrea	0.5	0.5		0.5			
Platyopuntia			0.5				
Unknowns	3.5	4.5	5.5	3.5	4.0	4.5	5.5
Total Grains Counted	**200**	**200**	**200**	**200**	**200**	**200**	**200**
	Aggregates						
	Ch-4 (1)	Ch-3 (5)		Lo-2 (5)	Hi-5 (1)	Lo-4	Lo-2 (1)
				Ar-2 (1)	Ch-2 (1)	Hi-3 (1)	Lo-20
				Ch-2 (5)		Ch-30 (5)	Ch-2 (1)
				Gr-3 (1)		Gr-2 (1)	
						Gr-10	

DEPOSIT:	**LT LATE**	**LT LATE**	**LT EARLY**	**LT EARLY**	**PETTS**	**PETTS**
HORIZON:	**Ck3**	**Ck4**	**E'**	**B'tk**	**2Btk1**	**2Btk2**
CONTEXT:	**ALLUVIAL FAN**	**ALLUV. FAN**	**ALLUV. FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**
DEPTH (cm):	**120**	**140**	**153**	**183**	**218**	**238**
Arboreal Pollen						
Picea		X				
Pseudotsuga					X	
Pinus edulis-type	0.5	1.0	0.5	1.0	0.5	1.0
P. ponderosa-type	X	1.5	1.0			X
Pinus	0.5			0.5	0.5	0.5

Table IX-3, continued

DEPOSIT:	**LT LATE**	**LT LATE**	**LT EARLY**	**LT EARLY**	**PETTS**	**PETTS**
HORIZON:	**Ck3**	**Ck4**	**E'**	**B'tk**	**2Btk1**	**2Btk2**
CONTEXT:	**ALLUVIAL FAN**	**ALLUV. FAN**	**ALLUV. FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**
DEPTH (cm):	**120**	**140**	**153**	**183**	**218**	**238**
Arboreal Pollen, continued						
Juniperus	1.0	2.5	4.0	3.5	0.5	0.5
Quercus				1.0	0.5	
Salix				0.5		
Prosopis		1.0				
Nonarboreal Pollen						
Low-spine Compositae	20.5	23.0	16.5	24.5	16.0	22.0
High-spine Compositae	3.0	9.5	5.0	5.5	8.5	22.0
Artemisia	2.0	1.0		6.0	3.0	2.0
Cheno-am	59.5	41.0	59.5	40.0	55.0	33.0
Tidestromia-type	0.5			0.5		
Graminae	9.5	11.0	7.5	11.0	10.5	10.0
Dithyrea-type						0.5
Cruciferae		0.5		1.0		
Ephedra torreyana-type		0.5	0.5	0.5		
Euphorbia-type	1.0	1.0	2.0			
Sphaeralcea-type	X	1.0	0.5	X	0.5	1.5
Boerhaavia-type	X	X	X	1.0	0.5	X
Plantago		0.5	0.5			
Eriogonum		0.5		1.0		
Calandrinia			X			
Portulaca			X			
Kallstroemia-type			X			
Larrea		0.5		0.5	0.5	1.0
Platyopuntia		X		X		X
Unknowns	2.0	4.0	2.5	3.0	3.5	5.5
Total Grains Counted	**200**	**200**	**200**	**200**	**200**	**200**
	Aggregates					
	Ch-7 (5)	Ch-5 (5)	Ch-3 (5)	Hi-2 (1)	Lo-5	Hi-2 (1)
	Ch-25	Ch-40	Ch-30	Cr-2 (1)	Ch-2 (5)	Ch-3 (1)
		Gr-3 (5)				Ch-20
		Gr-14				

NOTE: Samples with insufficient pollen were 2Btk3 and 2Btk4.

Of the 15 pollen samples evaluated from the sequence, 1 surface sample, 2 historic dune, 8 from mostly Holocene (Lake Tank late and Late Tank early), and 4 from pre-Holocene deposits were evaluated. All but the deepest two samples produced sufficient pollen for counts.

The modern surface control sample, which was collected as a pinch sample across about a 50-m-square area, is dominated by Cheno-am pollen. This probably relates to the abundance of saltbush in the area. Composites and grass are represented relatively well in the nonarboreal pollen (NAP), and probably reflect local-source plants, such as those recorded in the modern flora. Snakeweed, for example, is subsumed in the High-spine Compositae category; cocklebur is subsumed in the Low-spine Compositae category. Several other NAP taxa have correlates in the modern vegetation. This includes joint-fir, mustard, globemallow, and creosotebush. Others, such as plantain and tidestromia-type, could have modern correlates that simply were missed in the limited modern vegetation recording that has occurred so far for the study locus. These pollen taxa are consistent with the type of saltbush community that characterizes the area today.

Representations in the arboreal pollen (AP) include pines, juniper, oak, and pecan. With the exception of pecan, most of these occurrences reflect long-distance, wind-transported pollen from higher elevations in the nearby mountains. Pecan is not native to southern New Mexico, but commercial groves do occur in the region. Again, some ambient wind-transported pollen influx is evident. Thus, none of these arboreal occurrences shed much light on the modern vegetation/pollen rain correlation. The proportions of NAP taxa, however, do indicate a strong correlation between the modern vegetation and pollen rain for the study region, which can be used as an analog for interpreting the older Pleistocene/Holocene records.

The two historic dune pollen records are similar to the modern count. Cheno-am pollen dominates in both samples; composites are moderately well reflected. The grass values are lower than in the modern sample. The NAP taxa diversity is similar, with several additional taxa in evidence. Again, a few of these, such as spurge, have correlates in the modern vegetation; the remaining are consistent with a saltbush-dominated plant community. In the AP, most of the representations are extra-regional (pines, juniper, and oak), while pecan again was recorded in one sample, and mesquite pollen was observed in both dune samples. Although mesquite is an important component of the modern flora, and apparently also the flora of the recent past, the genus is insect-pollinated and the pollen generally is underrepresented in soils from areas where the plants occur. The relative abundance of mesquite trees through time is not likely to be reflected well in the pollen results. Likewise, creosotebush in the NAP appears in only one of the two dune samples. Again, as an insect-pollinated plant with low pollen productivity, it is rarely represented in the soil pollen assemblages even when abundant. These facts are important to establish since they point out the limits of the pollen data for detecting certain major elements of Chihuahuan flora. The two dune records, however, still are diagnostic of a saltbush-dominated community comparable to the modern setting.

The six "Lake Tank late" samples exhibit many similarities with each other and with the overlying samples. With the exception of the "E" horizon sample at 45 cm in depth and the "Ck2" horizon sample at 100 cm in depth, they are dominated by Cheno-am pollen with Compositae pollen of secondary value. All suggest a saltbush-dominated community in the past. The "E" horizon sample exhibits co-dominance of Cheno-am and grass pollen. The 22-percent grass value is the highest of any of the Old Coe Lake samples. A notable 9-percent wild buckwheat value also occurs in this sample. Pollen of creosotebush and a variety of other NAP taxa, consistent with a saltbush-dominated desert scrub community, still were recorded, however. Possibly the grass and wild buckwheat pollen together indicate localized depositional circumstances different from the those contributing to the pollen accumulation in the other horizons. An example might be a lusher growth of grasses and herbaceous buckwheat in a moist depression, with subsequent entrapment of the local

pollen assemblage by rapidly accumulating overlying dune sediments. It is not necessarily the case, then, that the higher grass value reflects a widespread grassier condition at this immediate prehistoric horizon, although this is a possibility. The "Ck2" sample exhibits co-dominance of Cheno-am and Low-spine Compositae pollen with a moderate grass value (10 percent). With the exception of a lack of strong Cheno-am dominance, the record is similar to other "Late Tank late" counts. For most of the sequence then, desert scrub conditions apparently are in evidence. The deepest of the "Lake Tank late" samples (Horizon Ck4), for example, looks similar to the historic C1 dune record, with a substantial taxa diversity in evidence and many similarities in the represented taxa. Thus no obvious suggestions of Holocene vegetation fluctuations are evident in these pollen samples.

The two "Lake Tank early" samples, from Horizons E' and B'tk dating 8-15 ka, are not substantially different from the majority of records from the overlying deposits. Both samples are dominated by Cheno-am pollen. Creosotebush pollen was recorded in Horizon B'tk along with a rare occurrence of willow pollen in the AP. Although willow is a riparian indicator, it also is wind-pollinated, and its occurrence here could be indicative of regional or extra-regional rather than local presence of a riparian stand. On the whole, these two "Lake Tank early" samples also suggest desert scrub conditions. It was anticipated that these samples would reflect a different type of pollen rain (possibly grass-dominated) because of their pre-Altithermal and Pleistocene/Holocene boundary stratigraphic position in the Old Coe Lake Gully sequence. It can be noted that the mean pollen concentration values (see Table IX-1) for these two samples remain as high as for the overlying deposits. Possibly the pollen assemblages are younger in age than their stratigraphic placement, or reflect a mixing of older and younger pollen as a result of some form of natural bioturbation. It is not clear what factors are influencing the counts, but the two records are not strongly suggestive of any notably different vegetation regime in the pre-Altithermal, or vegetation shift across the Pleistocene/Holocene boundary.

A change is seen in mean pollen concentrations in the Petts Tank deposits (see Table IX-1), dating to 25-75 ka. Concentration values drop significantly, and the deepest two samples from the Old Coe Lake sequence failed to produce sufficient pollen for counts. Despite this obvious shift in pollen abundance/preservation, the actual pollen records remain very similar to the overlying deposits. Again Cheno-am pollen dominated in both samples, with composites of secondary value. Creosotebush pollen was recorded in both samples. The remaining NAP taxa diversity was consistent with desert scrub conditions. Thus, no major contrast in vegetation is indicated despite the much older age of the deposits.

In summary then, the Old Coe Lake Gully sequence was, in general, very productive of pollen. The records, however, suggest vegetation similarity and stability through a long period of time, rather than the fluctuations that were anticipated. It is possible that much of the pollen sequence is fairly young; not until the Petts Tank records do mean pollen concentrations drop to levels suggestive of antiquity of the pollen rain. Even then, the actual pollen assemblages are very similar in makeup to the overlying horizons. The pollen assemblages, in general, might be younger than the sedimentary matrix, although additional study of the deposits is needed to substantiate this possibility.

Booker Hill Gully

The Booker Hill Gully sequence is from the bank of an arroyo cutting distal alluvial fan deposits off the south end of the Organ Mountains. There is a gentle slope to the topography, and elevation is about 4100 ft (1250 m). Details on modern vegetation are incomplete but mesquite, creosotebush, yucca, and grasses occur in the area.

The upper Organ alluvial fan deposits are younger Holocene (post-Altithermal) in age (about 4 ka). An Archaic hearth occurred in the Btk1 horizon. The underlying Jornada II and I deposits are much older, pre-dating 25 ka. The deeper part of the sequence is truncated, and no deposits pertaining to the Pleistocene/Holocene boundary period were preserved.

Of the nine pollen samples studied from this locality, one was collected from an historic shrub coppice dune, three were collected in the younger alluvium, two were from Jornada II deposits, and three were from Jornada I levels. All but one of the Jornada I samples produced sufficient pollen for counts (see Table IX-4).

The record from the dune (Horizon C) is dominated by Cheno-am pollen (28 percent) with composites and grass (17.5 percent) of secondary value. Creosotebush pollen and a broad variety of NAP taxa are represented. All of these could reflect local or regional plants. The NAP taxa diversity is similar to that at the Old Coe Lake locality. Saltbush probably was present locally, although it is not mentioned in the modern vegetation list. A desert scrub community with saltbush appears to be reflected in the pollen rain. A limited variety of AP taxa (pines, juniper, oak) are evident in the dune sample; all are extra-regional in origin.

The three Organ alluvial samples (including the hearth record) all are strongly dominated by Cheno-am pollen. Values (56.5 to 60 percent) are much higher than in the dune sample. Moderately low grass values of 10 percent or less were recorded. Creosotebush pollen appears in two samples, and mesquite in one. On the whole, the results suggest a desert scrub, probably saltbush/mesquite type community with some associated creosotebush in the vicinity. Vegetation conditions, in general, might have been similar to modern conditions at the Old Coe Lake Gully locality, with on-site saltbush abundance. Cultural impacts on past vegetation from the occupation associated with the hearth are not clearly evident in the pollen rain.

Table IX-4. Pollen Results from Booker Hill Gully

KEY:

Ch = Cheno-am   Gr = Gramineae   Lo = Low-spine Compositae
Cr =   Hi = High-spine Compositae   Ti = *Tidestromia*-type

DEPOSIT:	**DUNE**	**ORGAN**	**ORGAN**	**ORGAN**	**JORNADA II**	**JORNADA II**	**JORNADA II**	**JORNADA II**
HORIZON:	**C**	**Btk1**	**Btk1**	**Btk2**	**2Btk1**	**2Btk2**	**3Btk1**	**3Bk**
CONTEXT:	**DUNE**	**HEARTH**	**ALLUV. FAN**	**ALLUV. FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**
DEPTH (cm):	**5**	**30**	**40**	**60**	**80**	**110**	**140**	**215**
Arboreal Pollen								
Pseudotsuga								1.0
Pinus edulis-type	2.0	0.5	0.5	2.0	0.5			
P. ponderosa-type	1.0		X					
Pinus	0.5				0.5			
Juniperus	2.0	1.0	1.5	2.0	1.0		0.5	
Quercus	2.0		1.0		0.5	0.5		
Prosopis				0.5	0.5			

Table IX-4, continued

DEPOSIT:	DUNE	ORGAN	ORGAN	ORGAN	JORNADA II	JORNADA II	JORNADA II	JORNADA II
HORIZON:	C	Btk1	Btk1	Btk2	2Btk1	2Btk2	3Btk1	3Bk
CONTEXT:	DUNE	HEARTH	ALLUV. FAN	ALLUV. FAN	ALLUVIAL FAN	ALLUVIAL FAN	ALLUVIAL FAN	ALLUVIAL FAN
DEPTH (cm):	5	30	40	60	80	110	140	215
Nonarboreal Pollen, continued								
Low-spine Compositae	14.0	17.0	15.5	16.0	11.0	32.0	15.0	13.0
High-spine Compositae	12.5	5.0	9.0	5.0	6.0	21.5	16.0	28.0
Artemisia	1.5		2.0		2.0	3.5	1.0	2.0
Liguliflorae	0.5							
Cheno-am	28.0	60.0	56.5	57.5	66.0	15.5	23.5	23.0
Tidestromia-type	0.5	7.0	0.5	1.0	1.0		0.5	1.0
Gramineae	17.5	5.5	9.0	10.0	7.0	11.5	31.0	19.0
Cruciferae	9.0			1.0	0.5	1.0	1.0	1.0
Ephedra nevadensis-type	0.5							
E. torreyana-type	1.5			1.0				
Euphorbia-type	1.0	0.5				1.5	0.5	1.0
Papilionoideae	0.5							
Sphaeralcea-type	0.5			0.5	0.5	1.0		
Boerhaavia-type	1.0	X	X	0.5		1.5		2.0
Mirabilis-type		X				X		
Plantago						0.5	0.5	
Eriogonum	0.5							
Calandrinia					0.5	0.5	1.0	
Portulaca			X					
Rhamnaceae						X		
Larrea	0.5	0.5	0.5					
Platyopuntia							0.5	
Unknowns	3.0	3.0	4.0	3.0	2.5	9.5	9.0	9.0
Total Grains Counted	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
	Aggregates							
	Hi-3 (1)	Ch-10 (5)	Hi-8	Ch-4 (5)	Ch-2 (1)	Lo-10 (5)	Ch-4 (5)	
	Ch-2 (1)	Ti-2 (5)	Ch-20 (5)			Hi-12 (1)	Gr-2 (1)	
	Cr-2 (1)	Gr-5 (1)	Ch-40			Ch-5 (1)		
			Ti-60					

NOTE: Sample with insufficient pollen was 3Btk2 190 cm alluvial.

Of the two Jornada II records, the Horizon 2Btk1 record (note high Cheno-am value) is very similar to the Organ results, while the deeper sample, Horizon 2Btk2 exhibits a markedly different pollen assemblage, much more similar to the Jornada I deposits. Considering the much greater age of the Jornada II deposits (25-125 ka), this might suggest substantial stability in vegetation from the early Jornada II through later Organ time. Alternatively, it is likely that elements of the pollen rain encompassed in the Organ deposits percolated down into the upper Jornada II levels, with the pollen rain thus being substantially younger than the deposit. It is not clear if this can be verified by further study of the stratigraphic sequence but it is one possible explanation for the pollen assemblage. The deeper Jornada II sample at Horizon 2Btk2, is probably more indicative of the vegetation circumstances that characterized the Jornada II period. This sample is dominated by Low-spine Compositae pollen with High-spine Compositae and Cheno-am pollen of secondary value. The grass representation is moderately low, 11.5 percent. Other NAP taxa are comparable to what appear in the desert scrub records, with globemallow, spiderling, and redmaids, for example, being represented. The pollen dominance expression, however, with its low 15.5-percent Cheno-am value, is distinctly not diagnostic of a saltbush-dominated desert scrub community, although this does not rule out the possibility that some other type of desert scrub facies could be reflected (see 90-1 discussion). Alternatively, the Compositae dominance in the 2BTk2 sample could reflect a forb or forb/shrub mix consistent with a grassland or semidesert grassland series (Brown 1982a, 1982b). Such plants as the globemallow and four o'clock seen in the 2Btk2 sample (see Table XI-4) characteristically occur in such communities (Brown 1982a:119), although they also are found in desert scrub settings. Cheno-am sources also can be components of grassland and semidesert grassland communities, so moderately low (and potentially even high) Cheno-am percentages would not be unlikely under such a vegetation regime. It seems fairly definite, in any case, that a different vegetation setting is evident in the Jornada II records, although the specific nature of the community is difficult to delineate.

The evidence for a different vegetation regime is further illustrated in the Jornada I records, which date to about 250-400 ka. The Horizon 3Btk1 record is dominated by grass pollen (31 percent), with Cheno-am pollen of secondary value. Both Low-spine and High-spine Compositae pollen are represented moderately well. The grass value is not as high in the other Jornada I sample (3Bk)–only 19 percent. This record actually is dominated by High-spine Compositae pollen (28 percent), followed by Cheno-am pollen, then grass, and Low-spine Compositae. In some respects it is similar to the Historic dune record, both at this site and at Old Coe Lake. Grass and Compositae values tend to be higher in the dune samples relative to the Cheno-am category. The proportions are sufficiently different, however, to suggest that depositional circumstances and vegetation setting were not especially similar. The Cheno-am values in the dune samples, for example, still are sufficiently high relative to proportions of other taxa to be suggestive of saltbush-dominated communities. This is not the case with the Jornada I samples. Although the actual Cheno-am values are not much lower than in the dune sample from this site, the combinations of the relative proportions of the major taxa seem suggestive of a vegetative regime other than desert scrub. Sample 3Bk implies semidesert grassland, while 3Btk1 actually might reflect a grassland setting.

Chihuahuan Desert distributions of grassland, semidesert grassland, and desert scrub are controlled by elevation, temperature, and moisture, with semidesert grassland occupying a position between lower elevation desert scrub and higher elevation chaparral, evergreen woodland, or plains grassland communities (Brown 1982a, 1982b:123, 1982c). If Pleistocene temperatures were cooler, semidesert grassland or grassland could have occupied the Booker Hill Gully region in the past at elevations (1,250 m) now occupied by desert scrub. This is within the lower elevational range (1,100-1,400 m) of semidesert grassland in the Chihuahuan Desert today (Brown 1982b:123). Thus, it seems likely that the pollen results are illustrating a

fairly substantial contrast in vegetation between the Pleistocene (250-400 ka) and Holocene (4 ka) in the Booker Hill Gully sequence.

Distinctly high grass values (up to 87 percent) have been recorded in pollen studies of Holocene and Pleistocene age deposits elsewhere in the Tularosa Basin (Von Finger and Horowitz n.d.). Microfossils of *Pediastrum* (colonial green alga) were present in their Site 1 study locality, indicating they probably had sampled a prior marsh location (Von Finger and Horowitz n.d.). The results, then, are not necessarily analogous to the alluvial fan type locations that are the focus of the current study. The results from the earlier study suggest Holocene climatic fluctuations that are not apparent in the alluvial fan sequences.

Franklin Mountain Arroyo

The Franklin Mountain Arroyo sequence is from the bank of an arroyo cutting distal alluvial fan deposits off the west face of the Franklin Mountains, south of the Organ Mountains. Elevation is about 4,200 ft (1,280 m). Details on modern vegetation are incomplete but creosotebush, yucca, and grasses occur in the area.

The Franklin Mountain Arroyo cut bank is a temporally truncated sequence. The uppermost A Horizon encompasses the modern ground surface and immediately underlying Jornada Ib deposits of great antiquity (250-400 ka). The deepest part of the deposit penetrates La Mesa sediments dating to about 400-1500 ka.

Table IX-5. Pollen Results from Franklin Mountain Arroyo

KEY:
Bo = *Boerhaavia*-type
Ch = Cheno-am
Gr = Gramineae
Hi = High-spine Compositae
Lo = Low-spine Compositae
Qu = *Quercus*

CONTEXT:	ALLUVIAL FAN	ALLUVIAL FAN	ALLUVIAL FAN
HORIZON:	**A**	**Bk**	**Bkm3**
Arboreal Pollen			
Picea	0.5		
Pinus edulis-type	3.5	0.5	2.0
P. ponderosa-type	0.5		1.0
Pinus	1.0	0.5	1.0
Juniperus	5.0	1.0	
Quercus	1.5		6.0
Juglans	X		
Carya	X		
Nonarboreal Pollen			
Low-spine Compositae	18.0	28.5	12.0
High-spine Compositae	16.5	29.5	18.0
Artemisia	5.0	2.0	6.0

Table IX-5, continued

CONTEXT:	**ALLUVIAL FAN**	**ALLUVIAL FAN**	**ALLUVIAL FAN**
HORIZON:	**A**	**Bk**	**Bkm3**
Nonarboreal Pollen, continued			
Cheno-am	26.0	21.0	21.0
Gramineae	11.5	6.0	23.0
Large Gramineae	X		
Cruciferae	0.5	0.5	
Ephedra nevadensis-type			1.0
E. torreyana-type	4.5	5.5	1.0
Euphorbia-type			1.0
Acacia	0.5		
Sphaeralcea-type	X		
Boerhaavia-type		X	1.0
Eriogonum	X		
Larrea	1.0	0.5	
Platyopuntia	X		
Unknowns	4.5	4.5	6.0
Total Grains Counted	**200**	**200**	**200**
	Aggregates		
	Gr-2 (5)	Hi-6 (5)	Qu-2 (1)
			Lo-2 (1)
			Ch-4 (1)
			Bo-2 (1)

NOTE: Samples with insufficient pollen were 2Btk, 2Btk1, 2Btk2, 2C, 3Bkm, 3Btk, and 3Bk

Of the ten pollen samples studied from this locality, only the upper three produced sufficient pollen for counts. This testifies to the great antiquity of the deposits, and the obvious loss of pollen through time. The mean concentration values (see Table IX-1) aptly illustrate the abrupt loss of pollen with age and depth. The mean value in the A Horizon was 37,667 grains per ml, which drastically drops to 6,843 per ml in the underlying Bk Horizon. The next sampling depth of 105 cm at Horizon Bkm3 yielded only 33 pollen grains per ml of sediment/soil, and the remaining samples yielded insufficient pollen for analysis.

The pollen records reflect a mixed vegetation picture. The A Horizon sample is dominated by Cheno-am pollen, but the value (26 percent) is relatively low. Compositae and grass are of secondary value. Creosotebush is represented in the record. The presence of pecan pollen in the AP (scanning) testifies to the recent/modern component of the pollen rain in this sample, while the indistinct pollen dominance pattern apparently testifies to mixture with the much older underlying sediment. A commercial pecan grove occurs a few miles to the north of the Franklin Mountain Arroyo study locality and is a likely source for the surficial pecan pollen. Other extra-regional AP taxa were recorded in low percentages. Or ole, the record is

fairly similar to the dune record at Booker Hill Gully. It is not strongly diagnostic of a saltbush community but appears more consistent with that community type than other potential communities. Actual field checking of the vegetation at Franklin Mountain Arroyo and probably more comprehensive modern pollen rain studies at Fort Bliss in general will be needed to accurately place this type of mixed record in relationship to modern pollen rain/vegetation type correlations.

The Bk Horizon sample also appears mixed. Composites (High- and Low-spine Compositae) dominate the record with Cheno-am of secondary value. The grass value appears suppressed here relative to the higher Compositae percentages. A grassland might not be in evidence, but a forb/shrub semidesert grassland mix might have contributed the pollen assemblage. Creosotebush pollen was recorded, which seems inconsistent with the antiquity of the deposit. It could be that percolation of some pollen from overlying soil is influencing this record; the Horizon Bk sample was collected only 7 cm below the modern ground surface (see Table IX-1).

The deepest sample that produced a count, from Bkm3 at 107 cm, exhibits co-dominance of grass, Cheno-am, and High-spine Compositae pollen (23, 21, and 18 percent, respectively). Again, a semidesert grassland community of grasses, shrubs, and forbs could be indicated. Certainly a saltbush-dominated desert scrub community is not implied. A count was obtained from this level with difficulty (note very low mean concentration of 33 grains per ml of matrix), and the pollen assemblage does appear to relate to the age of the deposit. In this respect, the results parallel the findings at Booker Hill Gully (horizons 3Btk1 and 3Bk) for this time period (250-400 ka), and further suggest a significant contrast in vegetation at this elevation during the Pleistocene.

Ray's Fault Trench

The Ray's Fault Trench sequence is from a backhoe trench cut in a fault-trough depression. Elevation is about 1,210 ft (369 m). The modern vegetation includes mesquite, yucca, and grasses.

The Ray's Fault Trench deposits consist of Holocene Organ I and II dune sands overlain by historic shrub coppice dunes and eolian sheet deposits. The oldest for th[illegible]uence is about 7.0 ka.

Of the five samples studied from this locality, only t[illegible]ace sample and the upper 33-cm-level sample produced sufficient pollen for counts. The smaller sample volume that was processed (20 ml) probably contributed to the low pollen productivity.

The surface sample is dominated by Low-spine Compositae pollen with Cheno-am and High-spine Compositae of secondary value. Only a few other NAP taxa (sagebrush, grass, joint-fir, spiderling, and groundcherry/nightshade) are represented by very low values. The grass value of 1.5 percent is exceptionally low when compared to other study localities in the pollen analysis. A moderate diversity of AP was recorded in this surface sample, including a 12-percent pinyon-type pine value and 6 percent oak. These occurrences are inconsistent with the on-site community and probably reflect pollen influx from trees grown in nearby El Paso, Texas. It is not clear from the limited modern vegetation description which plants might be contributing to the dominance of the Low-spine Compositae taxon in this surface sample. The modern vegetation apparently could be classed as desert scrub, but with a shrub other than saltbush dominant. It will be useful to further study the modern plant community composition at this site to aid in characterizing modern vegetation/pollen rain correlations for Fort Bliss.

The sample at 33 cm below the modern ground surface is dominated by High-spine Compositae pollen (43 percent) with Cheno-am of secondary value. Other NAP taxa include composites, grass (only 3 percent), spurge, and spiderling (7 percent). This fairly shallow sample was collected at the boundary between the historic shrub coppice dune sands and Organ I deposits, and the pollen rain is of potentially young age. It is difficult to relate this high percentage of High-spine Compositae pollen to a particular plant community. If the assemblage is young, then it also is difficult to account for the marked differences in the record in comparison to the modern surface record. It is possible that some abrupt burying of a particular growth of composite species by sand is reflected in the 33-cm sample. The pollen record thus could reflect an isolated assemblage inconsistent with the surrounding plant community. Additional study of Ray's Fault Trench is needed to adequately address local pollen depositional dynamics.

SAK

Two samples (SAK 1 and SAK 3), submitted by Sa'eb Khresat, were evaluated. Details on this study locality are pending.

Only one of the two samples, SAK 1, produced sufficient pollen for a count. The preservation was poor with a pollen concentration of only 294 grains per ml of soil. The record is dominated by Low-spine Compositae pollen with Cheno-am pollen of secondary value. A 12-percent grass value was recorded. The pollen record could indicate semidesert grassland or grassland conditions. The assemblage must be viewed with some reservations, however, as a result of the poor preservation and the high proportion (22 percent) of eroded, unidentifiable grains that had to be classified as unknowns.

Trench 16

The two samples from Trench 16 (labeled "Army Trench" and "Trench 648") were caliche nodules, which dated to about 10 ka. The nodules were rinsed in distilled water and then crushed at NMSU before being shipped to Texas A&M University for processing. Neither sample produced sufficient pollen for counts.

90-1

The 90-1 samples are from a backhoe trench in distal alluvial fan deposits off the south end of the Organ Mountains. Elevation is about 4,100 ft (1,250 m). The modern vegetation is dominated by creosotebush; saltbush is locally absent. Associated plants include mesquite, prickly pear, yucca, snakeweed, various herbaceous composites, spurge, and grasses.

The 90-1 trench cuts Organ I, II, and III deposits over a Jornada II, late Pleistocene soil. The lowest Organ I sediments date to about 7.5 ka. Three pollen samples were collected: one surface control, one charcoal layer sample from the upper Organ I/Organ II boundary, and one Jornada II sample from the middle of the deposit.

The surface control sample exhibits co-dominance of Low-spine Compositae and Cheno-am pollen (19 percent for each taxon), with grass and High-spine Compositae pollen of secondary value. A broad diversity

of other NAP was recorded including low values of sagebrush, mustard family, joint-fir, spurge, catclaw, papilionaceous legume, plantain, groundcherry/nightshade, and gilia-type. Creosotebush accounts for 4.5 percent of the pollen rain, a relatively high value considering the insect-pollinated nature of the plants. In the AP, pines, juniper, and oak occur. A 1.5-percent mesquite pollen value was recorded. Pecan pollen was observed in scanning, reflecting the regional/extra-regional presence of commercial groves. Walnut pollen was recorded, reflecting wind-borne pollen influx from trees along regional/extra-regional water courses (for example, the Rio Grande) or trees grown elsewhere in the region.

The surface pollen record at 90-1 is not strongly diagnostic of the creosotebush community that currently characterizes the study locality. The desert scrub setting, in this case, is demonstrated primarily by a combination of moderate values of Compositae, Cheno-am, and grass pollen. As has been mentioned elsewhere in this report (see Booker Hill Gully discussion), this type of pollen rain also could be indicative of semidesert grassland or grassland communities. The 90-1 surface record thus illustrates the limitations of the pollen data for discerning certain desert scrub facies in the Chihuahuan Desert. Whereas, it appears possible to recognize saltbush-dominated desert scrub facies (in other words, desert scrub facies on fine-grained or more alkaline substrates), it is more difficult to differentiate desert scrub associations not dominated by Cheno-am plants and also difficult to separate them from semidesert grassland or grassland pollen rain expressions.

Larrea is perhaps the most diagnostic plant for hot desert, desert scrub vegetation. Identifying the presence of creosotebush pollen, then, is crucial for reconstructing past valley floor vegetation regimes. Since the pollen is generally underrepresented in soil, however, presence of such communities in the past might not be evident in the pollen rain even when the plants are common in the landscape. A further problem is the morphology of the grains themselves. *Larrea* grains are small (usually less than 20 µm in polar axis and 15 µm in equatorial diameter), tricolporate (having three furrows with equatorial pores, C3P3), tectate (with a layered grain wall), and reticulate (having a grain wall with a mesh-like pattern). The reticulum may be fine to coarse and the pores can vary from mere constrictions at the equator to more distinct pores forming a definite equatorial break in the furrow. While distinctive, this type of grain morphology is similar to the pollen of many other plants (as evident under light microscopy). With increasing depth and age and, concomitantly, decreasing quality of preserved detail, the potential for misidentification increases. This is important to keep in mind when considering the following subsurface results from 90-,1 where creosotebush pollen also was recorded in fairly ancient deposits.

The charcoal layer sample at 90-1 is strongly dominated by Cheno-am pollen, with Low-spine Compositae pollen of secondary value. Creosotebush pollen was recorded, along with a moderate diversity of other NAP taxa. Mesquite pollen was observed in the AP. As at Booker Hill Gully, the high Cheno-am value suggests substantial saltbush scrub in the past, probably with some mesquite. The creosotebush also suggests some similarity with the present desert scrub facies. Considering the 7.5-ka date of the charcoal layer, the creosotebush occurrence is not out of line with Holocene occurrences elsewhere in the Chihuahuan and Sonoran Deserts (Spaulding et al 1983:285). On the whole a transitional or mixed vegetation situation seems to be indicated for the charcoal layer at 90-1.

The deepest sample from 90-1 in Jornada II deposits provides yet again another contrasting record. This sample is dominated by Low-spine Compositae pollen (52 percent) with only moderate values of High-spine Compositae, Cheno-am, and grass pollen (12, 10, and 11 percent, respectively). A moderate NAP diversity, which included creosotebush pollen, was recorded. Other NAP taxa include spurge, globemallow-type, spiderling, four-o'clock-type, and prickly pear. Remarkable occurrences include the 6-percent red maids

(*Calandrinia*) value, and presence of smartweed (*Polygonum*) pollen (in scanning). It can be noted that in previous pollen studies in the region (Von Finger and Horowitz, n.d.), *"Liquidamber ?"* pollen was identified in several samples. This actually may be *Calandrinia*, since the pollen grains have a similar periporate (many-pored) morphology. Species of red maids are common early-spring annuals of the hot deserts, but are wide-ranging in geographic distribution and not ecologically diagnostic (Kearney and Peebles 1960:287-288). In the AP from the 90-1 Jornada II sample, occurrences of elm and willow pollen (scanning) are notable.

This Jornada II record is one of the most interesting samples in the project. In terms of a dominance pattern, the 52 percent Low-spine Compositae value is the highest, by far, of any of the studied samples. The combination of this high value of composite pollen with creosotebush pollen is actually a common type of assemblage seen in Holocene studies of the Sonoran Desert where creosotebush/bursage (*Larrea tridentata/Ambrosia* sp.) is a characteristic community. Numerous potential sources exist for the Low-spine Compositae pollen: *Hymenoclea* spp. and *Xanthium* spp. are examples. It is not possible to point to any specific genus as the probable source, but a desert scrub community could be indicated. If this is the case, it is difficult to explain the incongruous occurrences of elm, willow, and smartweed pollen, all of which are more mesic indicators. It is also difficult to explain the antiquity of the creosotebush occurrence, since the plants are not documented as present in the Southwest until about 10,000 B.P. (Spaulding et al 1983:276, 285), much younger than the pre-25,000 B.P. of the Jornada II deposit.

In regards to creosotebush, the earliest occurrences of well-dated *Larrea* occur about 10,500 and 10,000 B.P., although remains of the plants have been found in earlier Wisconsin times in Gypsum Cave, Nevada, and Rampart Cave, Arizona, far to the northwest of the current study area (Spaulding et al 1983:276, 285). Spaulding et al (1983:285) postulate that creosotebush has been present through much of the arid regions of North America since pre-Wisconsin times, despite the lack of well-dated remains. It also can be noted that since the Jornada II deposit substantially pre-dates the glacial maximum (around 18,000 B.P.), conditions might have been more mild and capable of supporting desert scrub vegetation at the 90-1 locality. Harris (1987:142), for example, suggests more mild conditions existed in southern New Mexico from about 60,000 to 25,000 B.P.. Thus, the creosotebush pollen occurrence in the Jornada II deposit at 90-1 is plausible, although still must be viewed with some reservations. As mentioned earlier, such factors as misidentification need to be considered. Also, considering the modern creosotebush presence at the study site, contamination during sample collection is another possibility. Further, bioturbation during some prehistoric episode might have resulted in downward pollen penetration. Thus, the pollen assemblage might not relate directly to the time of the Jornada II deposit, although the sample's low mean pollen concentration (401 grains per ml of soil) is suggestive of antiquity.

The elm and willow occurrences in the AP portion of the 90-1 Jornada II sample both are suggestive of a riparian arboreal community. The elm occurrence is particularly noteworthy since the plants do not occur naturally in New Mexico today; the easternmost distribution is in Texas. Elm, however, is both temporally and spatially widespread in the Pleistocene (Gish 1989). Since both of these trees are wind-pollinated, the occurrences in the 90-1 Jornada II sample might not indicate local presence. It is not necessarily the case that a riparian elm/willow stand occurred in juxtaposition with surrounding desert scrub. Still, there is the matter of the smartweed occurrence to consider. Species of smartweed, such as *Polygonum coccineum*, can be wide ranging in elevation but generally are found in wet habitats along ponds and marshes (Kearney and Peebles 1960:248). Although smartweed species can be wind- or animal-self-pollinated, it is likely the pollen would not disperse far from source plants, and the single occurrence in the 90-1 Jornada II sample is suggestive of local wet conditions.

In summary then, this deep sample poses a number of problems. The record suggests an incongruous juxtaposition of communities: elm/willow with desert scrub, and also perhaps a difference in the nature of the desert scrub community (dominated by Low-spine Compositae sources) that is not characteristic of Chihuahuan desert scrub today. Willow is a common component of desert wetlands and riparian stands ranging from desert to montane settings. Its' presence in the Pleistocene record is not unusual, and clearly could indicate local wet conditions in the past. The ecological implications of the elm, however, are somewhat unclear. Was the elm a warm-temperate elm or a cool-temperate species? Could it have been locally present in the valleys or does the pollen reflect wind-borne pollen influx from a montane source and hence a fortuitous association with the willow, smartweed, and desert scrub pollen assemblage in the 90-1 Jornada II sample? Much of the Pleistocene elm pollen in valley settings in the Southwest has been recovered in riverine deposits and probably is from sources in the river-system watersheds rather than of valley origin (Gish 1989). It must be kept in mind that a pollen record is a composite picture of local, regional, and extra-regional plants. Hence, it is not necessarily the case that the unusual grouping of pollen taxa in the 90-1 sample reflects plants growing together or near each other in one locality. Still, it seems clear that floristic elements were extant during the Jornada II time and did not occur later in the Holocene. In this respect, the 90-1 sample confirms the findings from the Jornada II deposits (especially 2Btk2) at Booker Hill Gully, which also demonstrate a marked vegetative difference, although the unique aspects of the 90-1 sample (occurrence of elm, willow, and smartweed) are not evident. One other sample evaluated in this study potentially dates to the Jornada II period. This is the 250- to 260-cm level sample from "lakeshore" sands in Profile 2. Interestingly, the pollen record replicates some of the findings of the 90-1 Jornada II sample.

Profile 2 and 3

One pollen sample each was evaluated from deep deposits in profiles 2 and 3. More information on the time period of the deposits at these localities is pending. Only the Profile 2 record produced sufficient pollen for a count. The modern plant community in the Profile 2 vicinity is characterized by mesquite and snakeweed. Associated plants include sand sagebrush (*Artemisia filifolia*), cocklebur, paperflower (*Psilostrophe* sp.), aster (*Aster* sp.), thistle (*Cirsium* sp.), various other herbaceous composites, globemallow, nightshade (*Solanum* sp.), jimson weed, wild gourd (*Cucurbita* sp.), yucca, spurge, milkweed (*Asclepias* sp.), prickly pear, joint-fir, wild buckwheat, stick-leaf (*Mentzelia* sp.), and various mustards, including pepper grass (*Lepidium* sp.), and grasses. The site is near the road and a water tank and has been burned recently, so is both disturbed and more mesic than elsewhere.

The Profile 2 record exhibits co-dominance of Cheno-am and Low-spine Compositae pollen. Moderate values of grass pollen (12.5 percent) and High-spine Compositae pollen (7.5 percent) were recorded. Other NAP taxa include low values of sagebrush, tidestromia-type, mustard, spurge, spiderling, and creosotebush. In the AP, pines, juniper, oak, willow, and elm are represented. Thus, the record is similar to the 90-1 Jornada II count in the overlap of elm, willow, and creosotebush, although in the dominance pattern the count is more similar to the "Ck2" Holocene record at the Old Coe Lake Gully site.

The co-dominance of Cheno-am and Low-spine Compositae pollen suggests a desert scrub situation or possibly semidesert grassland. The creosotebush occurrence points to desert scrub, but again must be viewed with some reservations because of the reasons already expressed. The willow and elm point to the existence of a riparian habitat. But again, it remains unclear if the elm reflects locally occurring trees or long-distance wind transport of pollen. Certainly, however, the Profile 2 record suggests Jornada II vegetation conditions were distinctly different from those that characterize the locality today.

Table IX-6. Other Pollen Results from Fort Bliss

KEY:

RFT = Ray's Fault Trench	Ch = Cheno-am	La = Larrea
Bo = Boerhaavia-type	Gr = Gramineae	Lo = Low-spine Compositae
Ca = C	Hi = High-spine Compositae	Ti = Tidestromia-type

SITE:	**RFT**		**SAK1**	**90-1**			**Pr-2**
CONTEXT:	**SURFACE CONTROL**	**33cm**		**SURFACE CONTROL**	**CHARCOAL LAYER**	**ALLUVIAL FAN**	**LAKE-SHORE**
SAMPLE:					**1**	**2**	**3**
Arboreal Pollen							
Picea	X			X			
Pinus edulis-type	12.0	3.0	5.0	1.0	X	X	0.5
P. ponderosa-type	1.0		1.0	0.5			X
Pinus			1.0			0.5	
Juinperus	0.5		2.0	6.5	1.5	X	3.0
Quercus	6.0			1.5		0.5	2.0
Salix						X	0.5
Carya				X			
Juglans	0.5			X			
Ulmus						X	1.0
Prosopis				1.5	0.5		
Nonarboreal Pollen							
Low-spine Compositae	35.0	13.0	33.0	19.0	22.5	52.0	24.5
High-spine Compositae	19.5	43.0	4.0	13.0	5.5	12.0	7.5
Artemisia	0.5	1.0	3.0	1.0	1.5	1.5	1.5
Liguliflorae		2.0					
Cheno-am	20.5	22.0	15.0	19.0	49.5	10.0	26.0
Tidestromia-type					0.5		1.5
Graminae	1.5	3.0	12.0	13.5	3.0	11.0	12.5
Cruciferae			1.0	1.5	0.5		0.5
Ephedra nevadensis-type				X			
E. torreyana-type	1.5			1.0			
Euphorbia-type		2.0		3.5	1.5	0.5	1.0
Acacia				0.5			
Papilionoideae				1.0			
Sphaeralcea-type				1.0		0.5	
Boerhaavia-type	X	7.0			3.5	1.0	1.0
Mirabilis-type					X	X	
Plantago				0.5			

Table IX-6, continued

SITE:	RFT		SAK1	90-1			Pr-2
CONTEXT:	SURFACE CONTROL	33cm		SURFACE CONTROL	CHARCOAL LAYER	ALLUVIAL FAN	LAKE-SHORE
SAMPLE:					1	2	3
Nonarboreal Pollen, continued							
Gilia-type				X			
Eriogonum				1.5	X		
Polygonum						X	
Calandrinia						6.0	
Phsalis/Solanum	0.5			0.5			
Kailstroemia-type					X		
Larrea				4.5	2.0	0.5	3.0
Cylindropuntia					X		
Platyopuntia						X	
Unknowns	1.0	4.0	22.0	9.0	7.5	4.0	14.0
Total Grains Counted	**200**	**200**	**200**	**200**	**200**	**200**	**200**
	Aggregates						
	Lo-2 (5)	Hi-10 (5)	Hi-2 (1)	Ca-2	Hi-11 (5)		Ti-3 (1)
	Hi-4b (20)	Ch-15 (5)		Hi-2 (1)	Ch-10b (15)		Ch-4 (1)
	Ch-7c (40)				Gr-2 (1)		La-2 (5)
	Bo-7				Bo-2		

NOTE: Samples with insufficient pollen were RFT 85-cm, 110-cm, and 150-cm levels; SAK 3; Trench 16's Army Trench and Trench 648; and Profile 3 270-cm level.

Conclusion

In conclusion, the pollen results seem to correspond fairly well with the temporally different depositional circumstances and do suggest changes in vegetation regimes through time. The sequence at the Old Coe Lake Gully is primarily young, although extending back into the Pleistocene, and the associated pollen results seem mostly indicative of younger saltbush desert scrub. The Booker Hill Gully locality has both distinctly young and much older Pleistocene deposits and the associated pollen rain indicates a marked contrast between Holocene desert scrub and Pleistocene grassland or semidesert grassland vegetation. The Franklin Mountain Arroyo site has a truncated Pleistocene sequence, and the uppermost pollen sample shows a mix of modern and ancient desert scrub and semidesert grassland, with a more reliable picture of semidesert grassland in the one deeper Pleistocene sample that was productive. The Ray's Fault Trench samples are suggestive of a recent vegetation shift. The SAK 1 sample probably reflects semidesert grassland. The 90-1 records suggest marked differences in vegetation conditions in the Holocene and Pleistocene in contrast to the present. The deepest Jornada II 90-1 sample and the Jornada II sample from Profile 2 indicate the past existence of now extinct floristic elements, with the 90-1 sample also raising the possibility of a grouping of plants unlike community composition of later times.

High Cheno-am percentages are seen as diagnostic of desert scrub vegetation (saltbush desert scrub), while high Compositae and grass percentages with lower Cheno-am values are seen as diagnostic of semidesert grassland and grassland. Desert scrub communities not dominated by saltbush also might be in evidence. Additional study of the plant community physiognomy implications and Pleistocene/Holocene distributions of such taxa as *Tidestromia*-type, *Calandrinia*, *Kallstroemia*-type, *Boerhaavia*-type, and *Sphaeralcea*-type, might prove useful for better delineating the past plant communities.

The current study shows the greatest degree of vegetation contrast between much older Pleistocene versus Holocene deposits. The Pleistocene/Holocene boundary period is not well represented in the stratigraphic sequences, only being present at the Old Coe Lake Gully sequence, and was not diagnostically reflected in the pollen rain. Thus, at least one major goal of the pollen analysis–to evaluate the nature of vegetation change across the Pleistocene/Holocene boundary–remains elusive. The distinctive Pleistocene versus Holocene vegetation contrasts, however, clearly indicate that pollen studies on the Fort Bliss Military Reservation can contribute greatly to perspectives of Quaternary climatic change in the region.

Chapter X

PHYTOLITH ANALYSIS OF BURIED SOILS IN THE FORT BLISS RESERVATION, EL PASO, TEXAS

By Brenda J. Buck

Introduction

Phytoliths are microscopic bodies of opaline silica that are deposited in and around the cells of certain plants. Soluble silica is believed to be dissolved through the roots of a plant along with other nutrients and then is carried through the vascular system until the loss of water forces the silica to be precipitated out. In most plants, opal phytoliths are concentrated in the leaves since most transpiration occurs there (Rovner 1971). For example, in conifers, phytoliths are concentrated primarily in the needles (Ollendorf et al. 1988). However, phytoliths also are found in bark, stem, and root portions of many plants and may strengthen parts of the plant or protect it against wilting (Rovner 1971). Phytoliths range in size from less than 1 micron to more than 500 microns, with the majority of identifiable types measuring less than 50 microns (Bartolome et al. 1986). Grasses probably are the most studied and best known for containing phytoliths, but phytoliths are present and identifiable in many types of plants.

Phytoliths are released and deposited into the soil by either the natural process of decay, during a forest or grass fire, or in the feces of herbivores (Pease 1967). This concentrates phytoliths in the A horizons of soils. Since phytoliths are composed of inorganic opaline silica they are resistant to organic decomposition. Opaline silica is not very soluble in the pH ranges of most soils (Pease 1967), which adds to its stability. Therefore it can be a useful indicator of past environments in buried soil horizons. In areas where buried A horizons are not otherwise readily identifiable, the presence of a high percentage of phytoliths may indicate an A Horizon (Pease 1967).

Where phytolith shapes and sizes are unique to certain plants, phytolith identification can be used along with other tools, such as pollen studies, to determine the paleoclimate and possibly an area's depositional and archaeological history. Phytoliths from four profiles in the Fort Bliss Reservation were studied to determine the paleoflora and paleoclimate of the area.

Methods

Samples of phytolith analysis were collected from four profiles on the Fort Bliss Reservation: Ray's Trench (775261), Booker Hill Gully (530580), Old Coe Lake (667625), and Franklin Mountain Arroyo (520513). Only samples that contained pollen grains were analyzed for phytoliths. Approximately 5 g of soil were weighed to four decimal places. The samples were placed in a 700- 800-ml beaker and calcium carbonate was removed using 1 M HC1. After the reaction was complete, water was added to a depth of 10 cm. After 1 hour the water was decanted, removing the clay fraction (Piperno 1988). This process was repeated seven to ten times until the liquid was clear. The samples then were allowed to dry and free iron-oxides were removed using the process described by Kunze and Dixon (1986). After the free iron-oxides were removed, the samples were washed thoroughly and dried in a low-temperature (110°C) oven. Organic matter was not removed because it was present in only very small amounts.

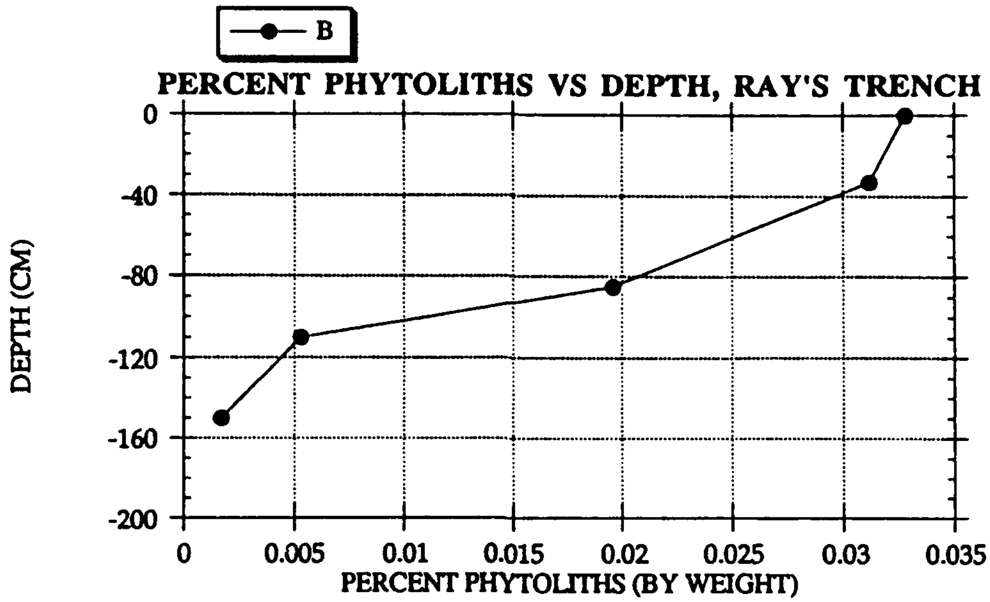


Figure X-1. Percent Phytoliths Determined by Weight in Ray's Trench (Samples taken at depths indicated by black dots.)

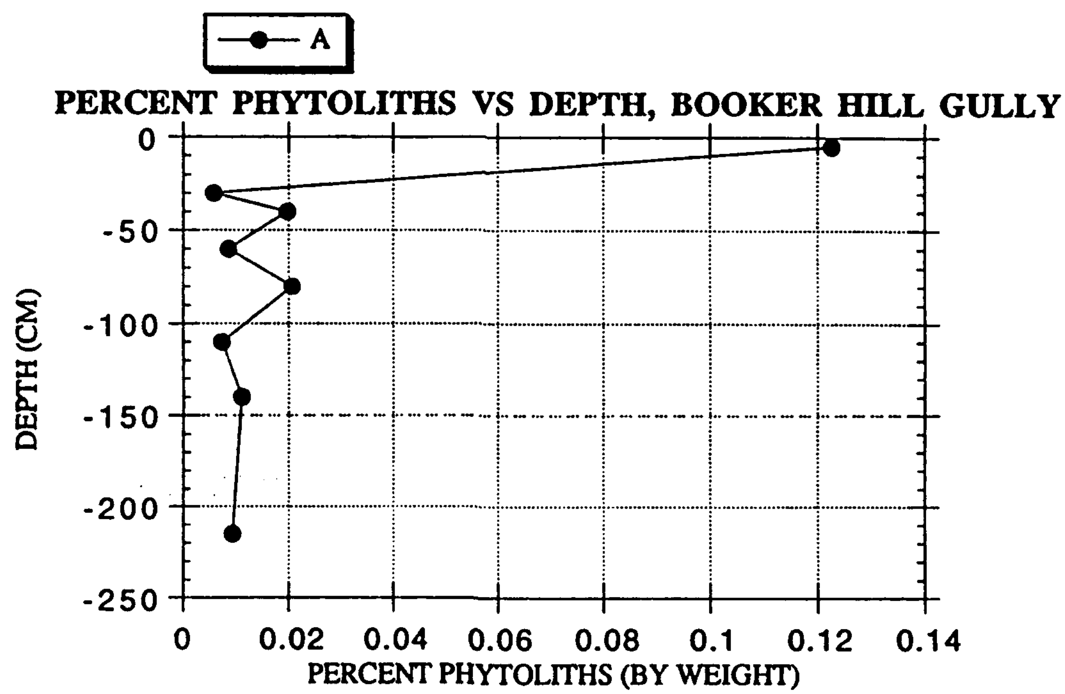


Figure X-2. Percent Phytoliths Determined by Weight at Booker Hill Gully (Samples taken at depths indicated by black dots.)

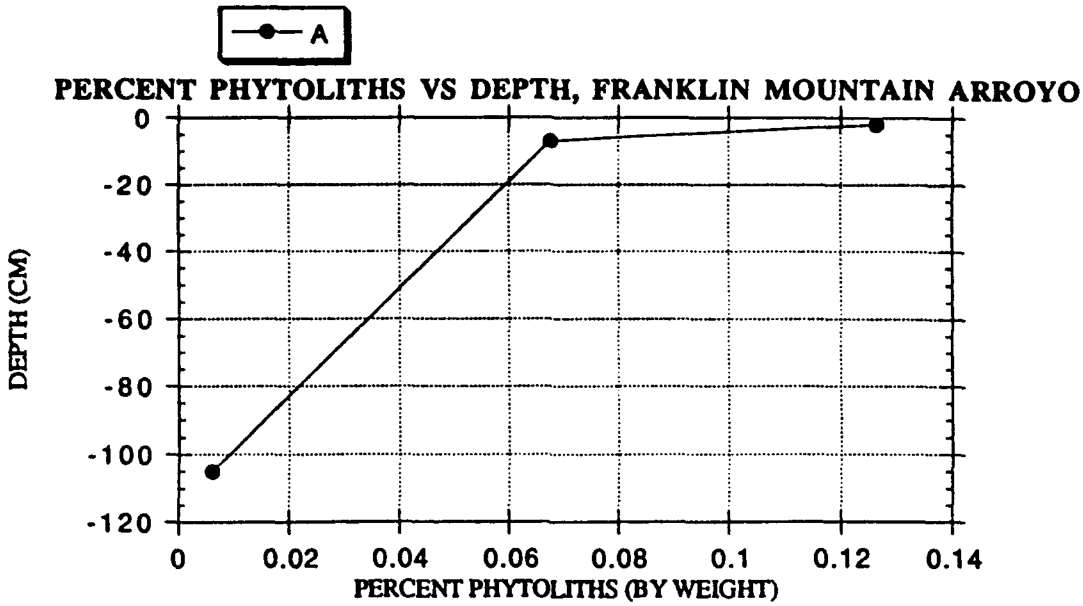


Figure X-3. Percent Phytoliths Determined by Weight at Franklin Mountain Arroyo (Samples taken at depths indicated by black dots.)

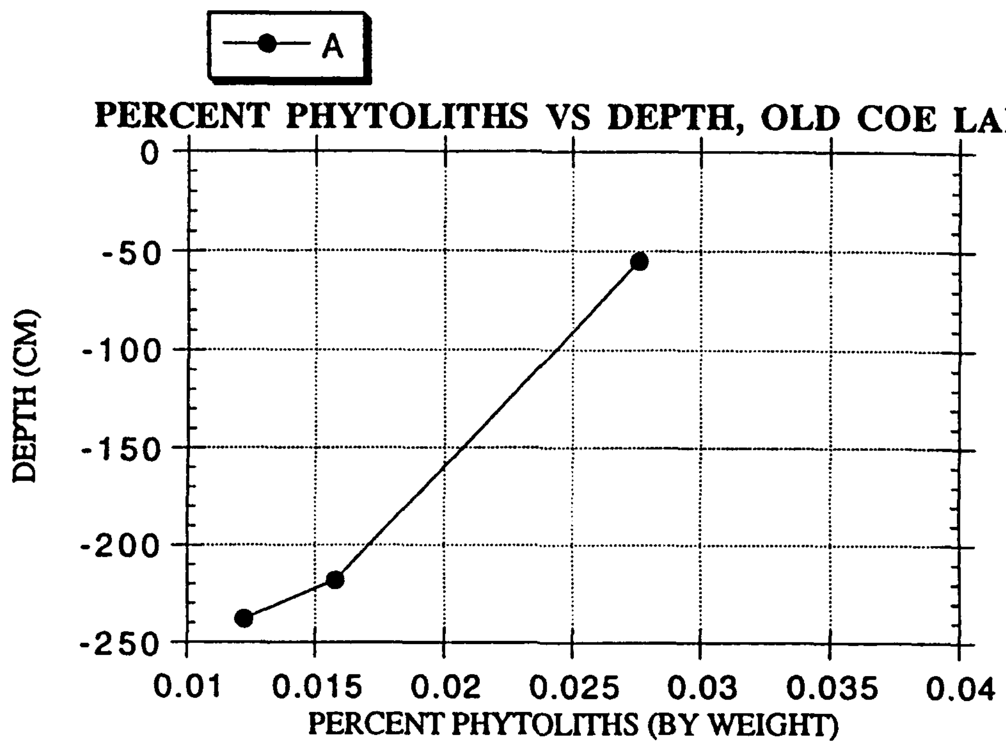


Figure X-4. Percent Phytoliths Determined by Weight at Old Coe Lake (Samples taken at depth indicated by black dots.)

Phytoliths were extracted using a heavy liquid solution. The specific gravity of opal phytoliths varies between 1.5 and 2.3. A solution of sodium metatungstate and water was created that had a specific gravity slightly higher than 2.3 in which the phytoliths floated. Approximately 10 ml of the heavy liquid solution was added to each sample and centrifuged at 3,000 rpm for 15 minutes. The supernatant liquid containing the phytoliths was decanted and water was added to reduce the specific gravity of the solution, causing the phytoliths to sink. The samples then were centrifuged at 3,000 rpm for 10 minutes and the liquid was decanted. This process was repeated approximately 10 times to ensure all of the sodium metatungstate was removed. The phytoliths then were allowed to dry, were weighed to four decimal places, and mounted on glass slides using liquid benzyl benzoate. The phytoliths were viewed in three dimensions by gently blowing upon the slide to flip them over. Benzyl benzoate was used to mount the phytoliths because of its suitable index of refraction (Piperno 1988). A Nikon petrographic microscope was used to examine the phytoliths. An estimation of purity for each sample was determined and was used to calculate the percentage of phytoliths by weight in each sample (see figures X-1 through X-5). The shapes and sizes of the phytoliths were documented first by hand drawings and later by photos (see figures X-6 through X-11, following "Conclusions"). An analysis of the hearth sample in Booker Hill Gully was performed using a scanning electron microscope at the Electron Microscope Lab at NMSU (see Figure X-12, following "Conclusions").

SAMPLE	PERCENT PHYTOLITHS
Trench 648	0.0042
Army Trench Lag	0.0239
Army Trench Plugged	0.0023

Figure X-5. Percent Phytoliths Determined by Weight for Other Samples

Interpretation

Since published keys of phytoliths for southwestern plants are not available, correlations of phytoliths in this study of plant species were not possible. Six samples from this study were sent to a private lab for identification. However, relative abundances for each sample were obtained (see figures X-1 through X-5). In every profile, the percentage of phytoliths decreased with depth, indicating downward movement of the phytoliths in the soil profile was minimal. The highest percentage of phytoliths occurred in the A Horizon of the Franklin Mountain Arroyo site and the coppice-dune or C Horizon, which is currently the landscape surface of the Booker Hill Gully site. Another coppice-dune was sampled at Ray's Trench. This coppice-dune also is the landscape surface; however, the percentage of phytoliths for this site were much lower. All other samples were taken from buried subsurface horizons, and therefore the lower percentage of phytoliths found was expected.

Although individual plant species were not identifiable from the phytoliths, the most common shape was the square or rectangle. These phytoliths would appear as squares or rectangles when lying on their side (see Figure X-6), however, when standing on end, they had a triangular shape (see figures X-7 and X-11). This shape was most easily viewed using the SEM (see Figure X-12). The square/rectangle phytoliths were most numerous in the A Horizon of the Franklin Mountain Arroyo site, the coppice-dune surface sample at Ray's Trench, and the coppice-dune surface sample at the Booker Hill Gully site. They also were common in the Organ Btk2 Horizon, the Jornada II Btk1 Horizon, and the Jornada I 3 Btk1 Horizon at the Booker Hill Gully site.

Other phytolith shapes included rectangles with serrated edges (see Figure X-8), "hooked" and "bulbous" (see Figure X-10), and possible "dumbbells" (see Figure X-11).

Conclusions

Although published keys for phytolith identification for southwestern plants are not available, the relative abundance of phytoliths down-profile in this study indicates little downward phytolith migration. With the development of keys for phytolith identification, phytoliths may be useful as indicators of past climates in buried soil horizons.

Figure X-6. Square/rectangle Phytoliths (viewed from the side) from the Jornada Ib Bk Horizon of the Franklin Mountain Arroyo Site (These are the most common forms of soil phytoliths found in this study. Field view is approximately 0.6 mm.)

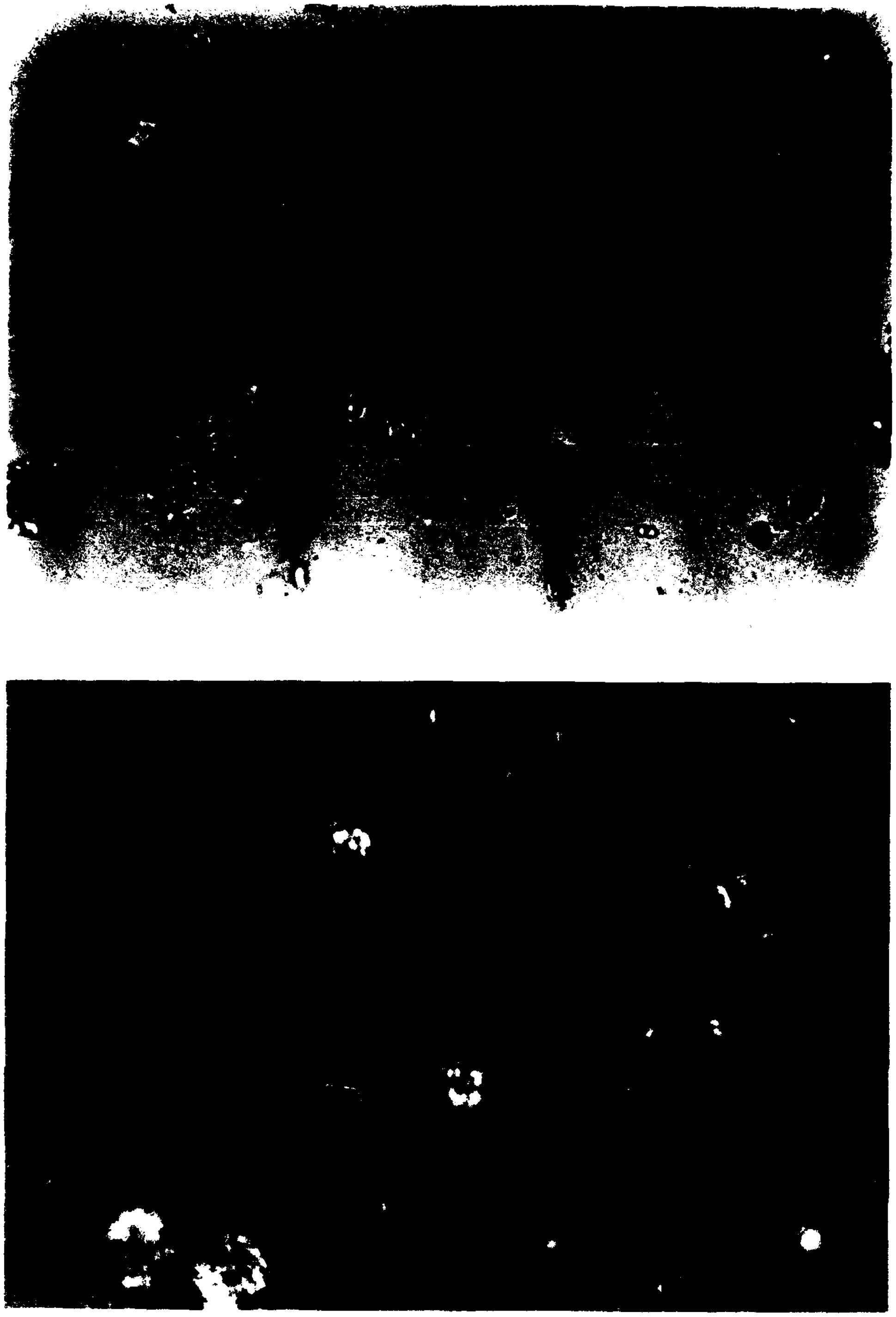


Figure X-7. Square/rectangle Phytoliths (viewed when standing on end) from the Jornada Ib Bk Horizon of the Franklin Mountain Arroyo Site
(Field view is approximately 0.6 mm.)

Figure X-8. Serrated Rod-shaped Soil Phytoliths from the Jornada Ib A and Bk Horizons of the Franklin Mountain Arroyo Site (Field view is approximately 0.6 mm)

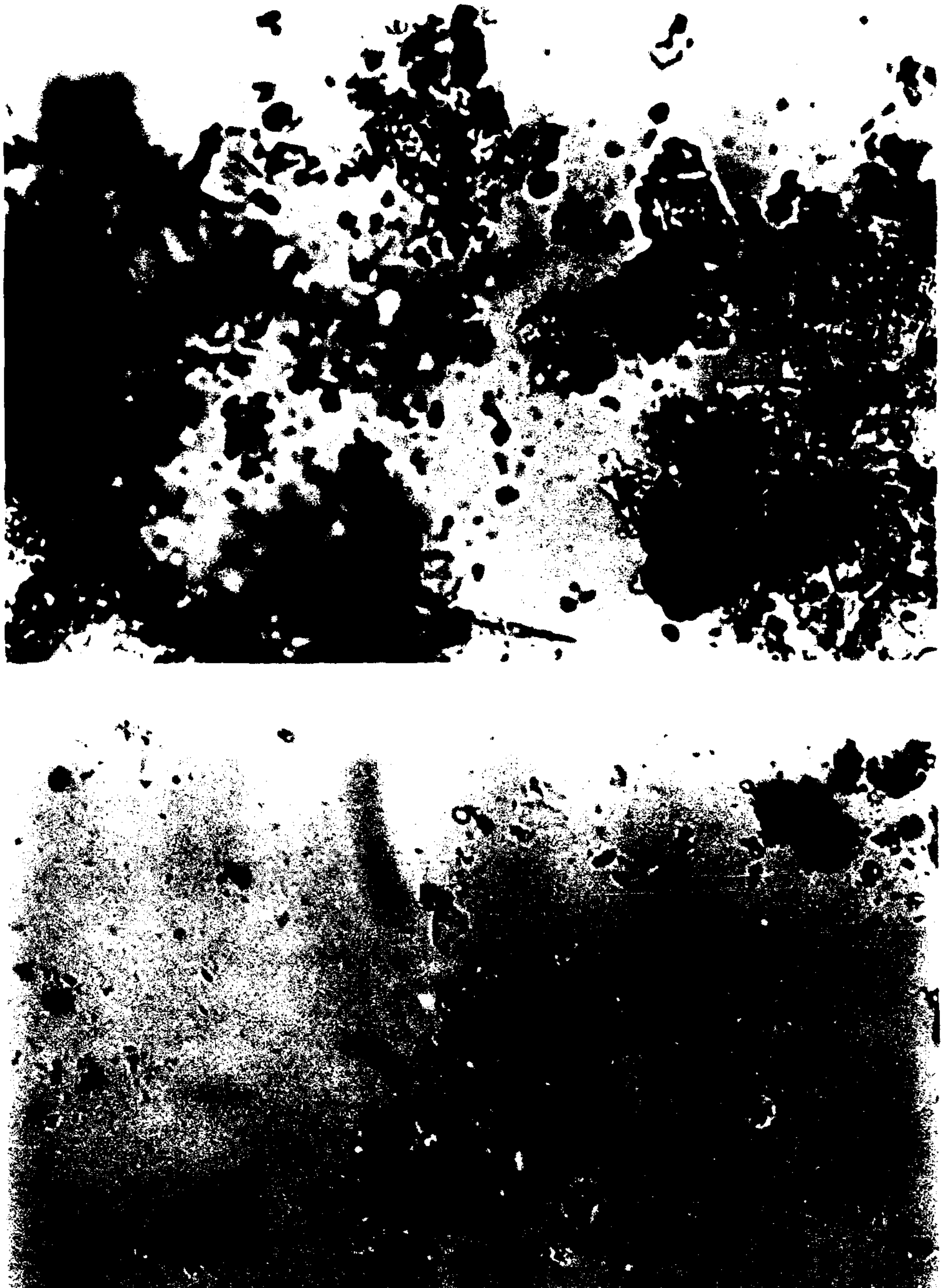


Figure X-9. Probable Silicious Perforated Root Platelets (similar photos in Drees et al. 1989) from the Jornada Ib Bk Horizon of the Franklin Mountain Arroyo Site (Field view is approximately 0.6 mm.)

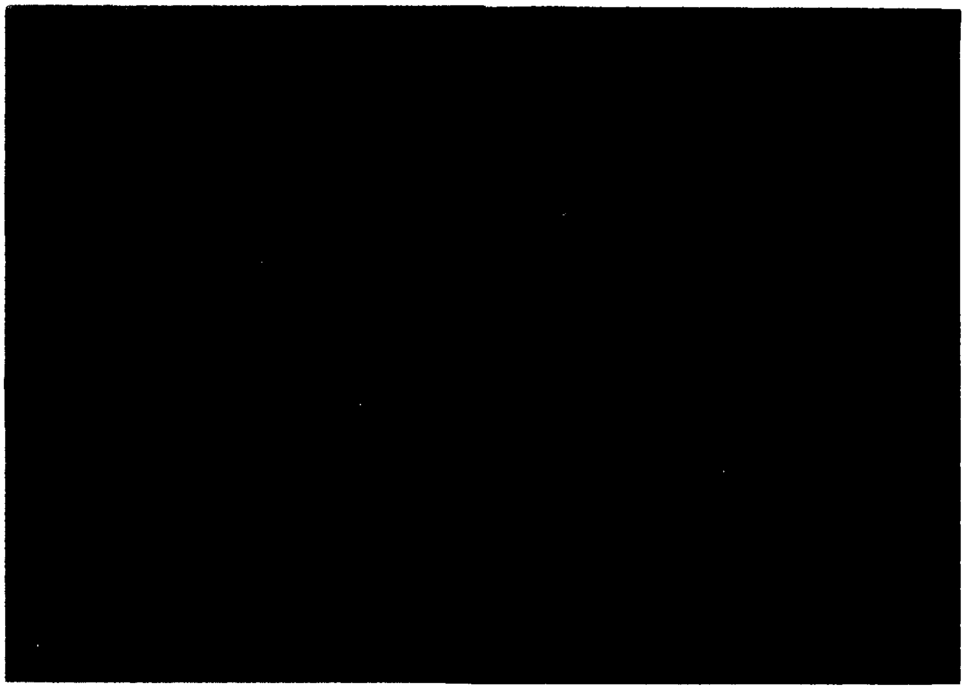


Figure X-10. Unknown "Hooked" (top) and "Bulbous" (bottom) Phytoliths from the Surface Coppice-dune Samples of the Booker Hill Gully Site (top) and Late Tank Late Btk Horizon of the Old Coe Lake Site (bottom) (Field view is approximately 0.6 mm.)

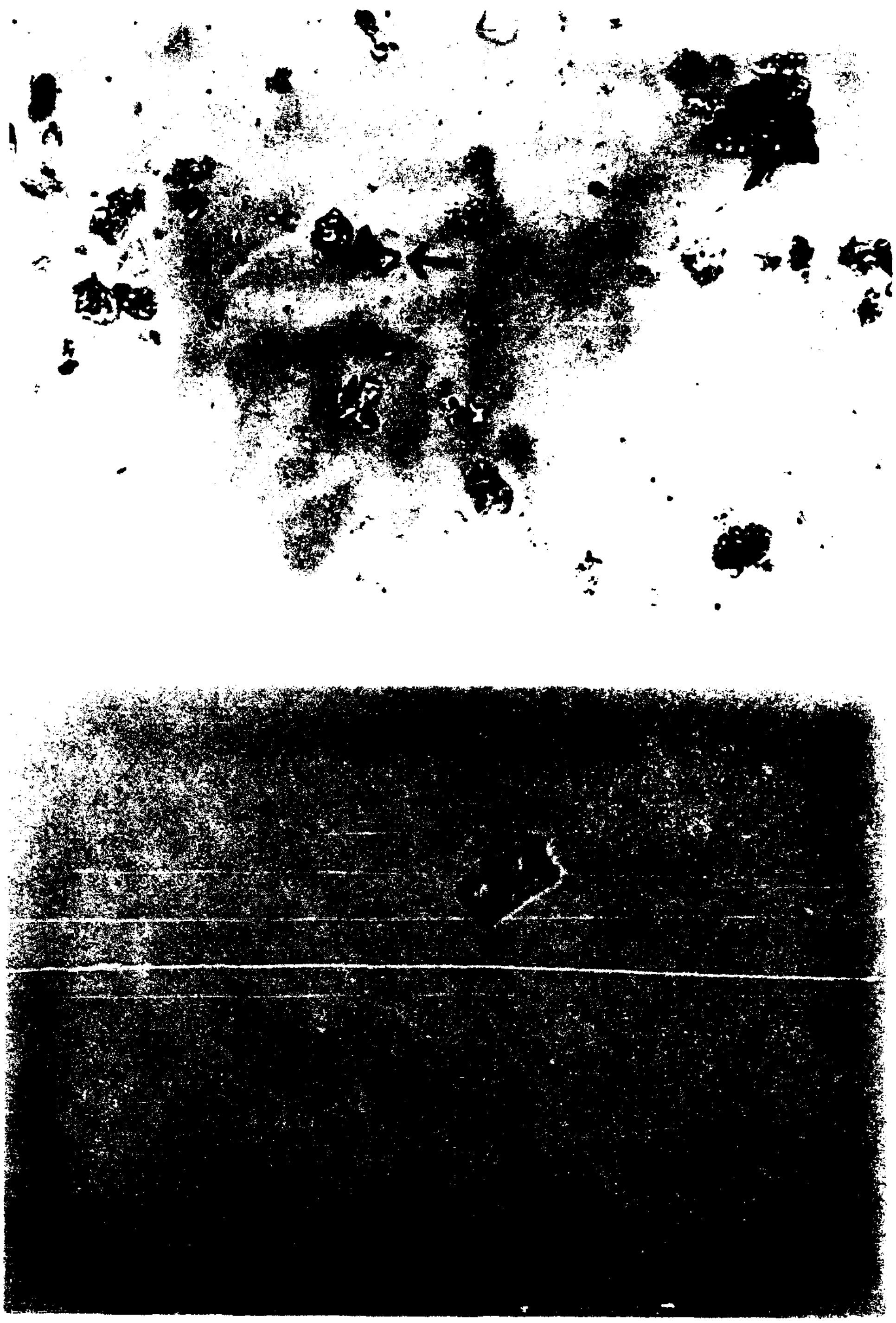


Figure X-11. Possible Dumbbell-shaped Phytolith (top) from Jornada Ib Bk Horizon of the Franklin Mountain Arroyo Site, and a Square/rectangular Phytolith (bottom) from Ray's Fault Trench (as viewed from the side and sampled at 110 cm) (Notice the center ridge in the bottom photo, indicating the phytolith's triangular "pup tent" shape. Field of view is approximately 0.6 mm.)

Figure X-12. SEM Photograph of a Square/rectangular Phytolith from the Hearth Sample of the Booker Hill Gully Site (as seen standing on end) (Field of view is approximately 0.25 mm.)

PHYTOLITH ANALYSIS OF THREE LOCATIONS ON THE FORT BLISS MILITARY RESERVATION, NEW MEXICO: A FEASIBILITY STUDY

By Linda Scott Cummings

Introduction

Six phytolith samples were selected from three study locations at the Fort Bliss Military Reservation in New Mexico for preliminary testing. The object of this study was to identify the potential for recovering phytoliths from these sediments, identifying the phytoliths present, and interpreting paleovegetation and paleoenvironmental conditions from the data base. The three profiles selected for this preliminary test wee the Old Coe Lake Gully site, Booker Hill Gully site, and Ray's Fault Trench.

Extraction of phytoliths from these sediments was based on heavy liquid flotation. Hydrogen peroxide (30 percent) was first used to destroy the organic fraction from 50 ml of sediment. Once this reaction was complete, 50 ml of sodium pyrophosphate (0.1 molar solution) was added to the mixture to suspend the clays. The sample then was sieved through 150-micron mesh (or 53-micron mesh if no large calcium oxylate crystals were expected). The sample was allowed to settle for two hours, then the supernatant, which contained clay, was poured off. This settling time allowed the phytoliths to settle to the base of the beaker. The samples were mixed with water, allowed to settle for two hours, and the supernatant discarded several times, until the supernatant was clear. The final two times the sample was allowed to settle only one hour. This procedure removed most of the clays. Once most of the clays were removed, the silt and sand size fraction was dried. The dried silts and sands then were mixed with zinc bromide (density 2.3) and centrifuged to separate the phytoliths, which will float, from the other silica, which will not.

Phytoliths, in the broader sense, may include opal phytoliths and calcium oxylate crystals. Calcium oxylate crystals are formed by *Opuntia* (prickly pear cactus) and are separated, rather than destroyed, using this extraction technique since it employs no acids. Any remaining clay is floated with the phytoliths, and is removed further by mixing with sodium pyrophosphate and distilled water. The samples then are rinsed with distilled water, followed by alcohols to remove the water. After several alcohol rinses, the samples are mounted in benzyl benzoate for counting with a light microscope at a magnification of 500x.

Discussion

Phytolith samples examined from three localities on the Fort Bliss Military Reservation represent both Holocene and Pleistocene sediments (see Table X-1). Vegetation in the study area includes sparse grasses *(Gramineae)*, creosote *(Larrea)*, mesquite *(Prosopis)*, tarbush *(Flourensia)*, and yucca *(Yucca)*.

Phytoliths are silica bodies produced by plants when soluble silica in the ground water is absorbed by the roots and carried up to the plant via the vascular system. Evaporation and metabolism of this water result in precipitation of the silica in and around the cellular walls. The general term phytoliths, while strictly applied to opal phytoliths, also may be used to refer to calcium oxylate crystals produced by a variety of plants, including *Opuntia*. Opal phytoliths, which are distinct and decay-resistant plant remains, are deposited in the soil as the plant or plant parts die and break. They are, however, subject to mechanical breakage and erosion and deterioration in high pH soils. Phytoliths usually are introduced directly into the soils in which the

plants decay. Transportation of phytoliths occurs primarily by animal consumption, man's plant gathering, or by erosion or transportation of the soil by wind, water, or ice.

Types of short-cell grass phytoliths recovered from this site include Festucoid, Chloridoid, and Panicoid. Elongate phytoliths are of no aid in interpreting either paleoenvironmental conditions or the subsistence record because they are produced by all grasses. Elongate phytoliths are easily broken in the soil, and because each fragment is counted as an individual phytolith, soil movement that serves to break the phytoliths also would increase the relative frequency of this type. For these reasons, elongate phytoliths were not included in the phytolith count. Phytoliths tabulated to represent "total phytoliths" included short-cell grasses only. Frequencies for all other phytoliths and other bodies recovered were calculated by dividing the number of each type recovered by the "total phytoliths."

The Festucoid class of phytoliths is ascribed primarily to the subfamily Pooideae and occurs most abundantly in cool, moist climates. However, Brown (1984) notes that Festucoid phytoliths are produced in small quantities by nearly all grasses. Therefore, while they are typical phytoliths produced by the subfamily Pooideae, they are not exclusive to this subfamily. Chloridoid phytoliths are found primarily in the subfamily Chloridoideae, a warm-season grass that grows in arid to semiarid areas and require less available soil moisture. Chloridoid grasses are the most abundant in the American Southwest (Gould and Shaw 1983:120). Panicoid phytoliths occur in warm seasons or in tall grasses that frequently thrive in humid conditions. Twiss (1987:181) also notes that some members of the subfamily Chloridoideae produce both bilobate (Panicoid) and Festucoid phytoliths. According to Gould and Shaw (1983:110) more than 97 percent of the native U.S. grass species (1,026 or 1,053) are divided equally among three subfamilies: Pooideae, Chloridoideae, and Panicoideae (Twiss 1987:181).

Other phytoliths recovered in this study include trichomes–produced by a variety of grasses, and a ridged elongate with unidentified affiliation.

Phytolith recovery was poor in five of the six samples examined. The majority of the silica recovered in all six samples was inorganic silica. No cells typical of mesquite and other legumes were recovered from any of the samples. A significant quantity of short-cell grass phytoliths were recovered only from sample 14 from Old Coe Lake Gully, with an age of 150-7000 B.P. (see Table X-2). This sample was dominated by Chloridoid phytoliths, representing grasses that thrive in warm, dry conditions. Panicoid phytoliths, preferring warm conditions and slightly more moisture, were second in numbers. Only a few Festucoid phytoliths were noted, representing cool-season grasses. Trichomes were rare, as were elongates, including both smooth and spiny forms.

It is impossible to identify positively whether the paucity of phytoliths is the result of poor conditions for phytolith preservation or to sparsity of grasses, resulting in deposition of extremely few phytoliths in local sediments. In light of recovery of probable *Gramineae* starch granules from samples 21 and 30, however, it appears that the near absence of short-cell grass phytoliths from these samples most probably is the result of adverse preservation conditions.

Summary and Conclusions

Phytoliths were recovered in sufficient quantity for analysis only from one sample, sample 14 from the Old Coe Lake Gully site. Other samples yielded virtually no short-cell grass phytoliths and extremely few

phytoliths or crystals that may be attributed to plants other than grasses. In light of the very poor recovery of phytoliths from these samples, further analysis of sediments from these locations on the Fort Bliss Military Reservation in New Mexico is not recommended.

Table X-1. Provenience Data

SITE	SAMPLE NO./ HORIZON	DEPTH (cm)	AGE (B.P.)	SAMPLE DESCRIPTION	PHYTOLITHS COUNTED
Old Coe Lake Gully	14/Btk	55	150-7000	Column	103
	21/2Btk1	218	25-75 ka	Column	0
Booker Hill Gully	33		3370 ±100	Hearth Fill	1
	30/3Btk1	190	250-400 ka	Column	2
Ray's Fault Trench	1	85	1100-2100	Column	1
	2	150	2100-7000	Column	3

Table X-2. Old Coe Lake Gully Site Phytoliths

PHYTOLITH	SAMPLE 1	SAMPLE 2	SAMPLE 14	SAMPLE 21	SAMPLE 33	SAMPLE 30
Festucoid		1	9		1	
Chloridoid			51			2
Panicoid Bilobate			39			
Elongate, Smooth		1	1			
Elongate, Spiny			2			
Elongate, Ridged		1				
Trichome			1			
Unidentified	1					
Starch				7		3

Chapter XI

SEDIMENTATION AND SOIL FORMATION IN MANEUVER AND ADJACENT AREAS ON FORT BLISS

By H. Curtis Monger

Alternating periods of sedimentation and soil formation contain information about climate change. Geomorphic evidence suggests arid periods are associated with landscape instability, while more humid intervals are associated with landscape stability (Hawley et al. 1976; Gile et al. 1981). Instability during arid periods would result as erosion-sedimentation increased following a vegetative-cover decrease. In contrast, landscape stability and soil formation would result during more humid periods as vegetative cover increased and curtailed erosion-sedimentation.

Organ Fan-Piedmont Alluvium

As indicated in Chapter III, multiple generations of alluvial fans surround the Organ Mountains. The youngest fan deposit is composed of Organ alluvium (Ruhe 1967). Based on radiocarbon dates of charcoal in the Desert Project, Gile and Hawley (1968) documented that Organ alluviation was initiated prior to 6400 B.P. Gile et al. (1981) placed the age of Organ at 7 ka and postulated that the onset of Organ sediments resulted from an increase in aridity. The 7 ka date seems reasonable for the Fort Bliss study area as well. At study Trench 91-1, Organ overlies Isaacks' Ranch alluvium that contain radiocarbon-dated nodules 9,070 years old. This date means Organ alluvium is younger than about 9 ka. Charcoal dates from Organ sediments at Trench 90-1 reveal Organ alluvium is older than 2.6 ka (see Figure VII-2) and dates from the Booker Hill Gully site indicate a date older than 3.4 ka (see Figure VII-6).

The 7 ka onset of Organ alluviation appears to be linked to the change in $\delta^{13}C$ values in fan-piedmont soils (see Chapter VII). For instance, study Trench 90-1 (see Figure VII-2) contains Organ sediments overlying Jornada II alluvium. The Jornada II plugged horizon (4Bk) has an inorganic radiocarbon date of 17,280 B.P. This date indicates the wetting front was reaching the plugged horizon and calcite crystals were precipitating at this time. Overlying the plugged horizon are stage I filaments in the Jornada II argillic horizon (4Btk). These filaments contain much lighter $\delta^{13}C$ values (see Figure VII-2), which implies a vegetative change from C-4 grasses to C-3 desert scrub. In addition, the formation of stage I filaments overlying the plugged horizon probably represents the upward shift in the depth of wetting caused by aridity. If the climate changed from wetter conditions to drier conditions, the depth of wetting and carbonate deposition would have risen above the plugged horizon and begun to deposit stage I filaments. Apparently soon after the climate change, the onset of Organ alluviation began and buried the Jornada II soil, stopping any further carbonate development.

Maneuver Areas 1B, 2C, and 2D

Holocene Age Eolian Deposits

There are at least four eolian deposits of Holocene age on the basin floor. Their diagnostic features and tentative ages are listed in Table IX-1. These eolian deposits have been correlated tentatively to the Organ I,

II, and III deposits in the Desert Project (Gile et al. 1981). Supporting the tentative age for Organ I are two samples from the 1x1 pit (see UTM 855296 and Figure I-3). This site gave ages of 3020 ±200 and 4170 ±200 B.P. The data were of inorganic carbon in stage I filaments. These filaments, composed of needle-shaped crystals that radiated into pores, were chosen for dating because their delicate morphology indicated *in situ* formation.

Table XI-1. Holocene Eolian Deposits (on the Basin Floor) and Their Diagnostic Features

DEPOSIT	DIAGNOSTIC FEATURE	TENTATIVE AGE ASSIGNMENT
Historic Blowsand	Stratified Eolian Sediments	1850 A.D. to Present
Organ III	No Eolian Strata, No Carbonate Filaments	100 to 1100 B.P.
Organ II	Faint Stage I Filaments	1100 to 2100 B.P.
Organ I	Prominent Stage I Filaments, Commonly 5-Year Hues, Faint Clay Skins	2100 to 7000 B.P.

Lag Deposits of Early Holocene Age

Lag deposits occur in the McNew Pipeline Trench (see UTM 880858 and Figure I-2), Trench 16 (see UTM 863284 and Figure I-3), Trench 7b (see UTM 855295 and Figure I-3), and Army Trench (see UTM 767299 and Figure I-3). These deposits are termed "lag" because they appear to represent a deflational surface where coarse fragments accumulated (lagged behind) as smaller particles blew away. The lag deposits are composed primarily of stage II carbonate nodules and ancestral Rio Grande pebbles.

Evidence that these layers have been concentrated by deflation and are "lag" deposits rather than a pedogenic horizons are as follows:

(1) The deposits have an abrupt (scoured-appearing) upper surface overlain by eolian sand deposits with few coarse fragments.
(2) The stage II nodules are admixed with ancestral Rio Grande pebbles that also would have been concentrated by deflation (although pebbles are less abundant than nodules).
(3) There is a high density of nodules at the top of the lag deposits that decreases with depth–suggesting concentration of nodules by their vertical collapse from overlying, wind-destroyed soils.
4) Cylindrical nodules lie in a haphazard arrangement, indicating they have been let down from above. Cylindrical nodules commonly are arranged vertically or diagonally in undisturbed La Mesa soils (Monger et al., 1991).

Lag nodules are significant because they may represent a period of aridity and deflation similar to the desertification event occurring today on parts of Fort Bliss. Dates of inorganic carbon lag nodules are 9930 ±70 for Trench 16, 9930 ±70 for the Army Trench, and 11320 ±70 for Trench 7b. These dates are similar to inorganic carbon dates for the Isaacks' Ranch deposits both in this study (see Chapter VII) and in the Desert

Project (Gile et al. 1981). These data imply that the period of deflation post-dated the formation of stage II nodules (i.e., sometime after about 10 ka). Thus, it seem likely this desertification event corresponds to the onset of Organ alluviation and the shift in C in the fan piedmont soils around 8 ka.

The 1x1 pit, which is close to Trench 7b, lacks lag nodules and may represent a paleodepositional area. Today, for example, depositional areas, such as coppice dunes and eolian sheet deposits, occur in close proximity to interdune deflation surfaces. The 1x1 pit may be in the location of an ancient dune or eolian sheet that was contemporaneous with the lag deposit.

Tobin Well Area

The Tobin Well pit (UTM 704274) consists largely of Organ II sediments overlying indurated caliche (see Figure XI-1). The Organ II deposit is buried in many places by Organ III. An underlying C horizon in the Organ III deposit and artifacts lying on the Organ II surface at Site 12441 are good evidence that Organ II and III are different deposits. Where Organ II is exposed at the land surface the artifacts are more easily discernable (Jerry William, personal communication). Organ I in this area occurred in a caliche pipe at Site 12433.

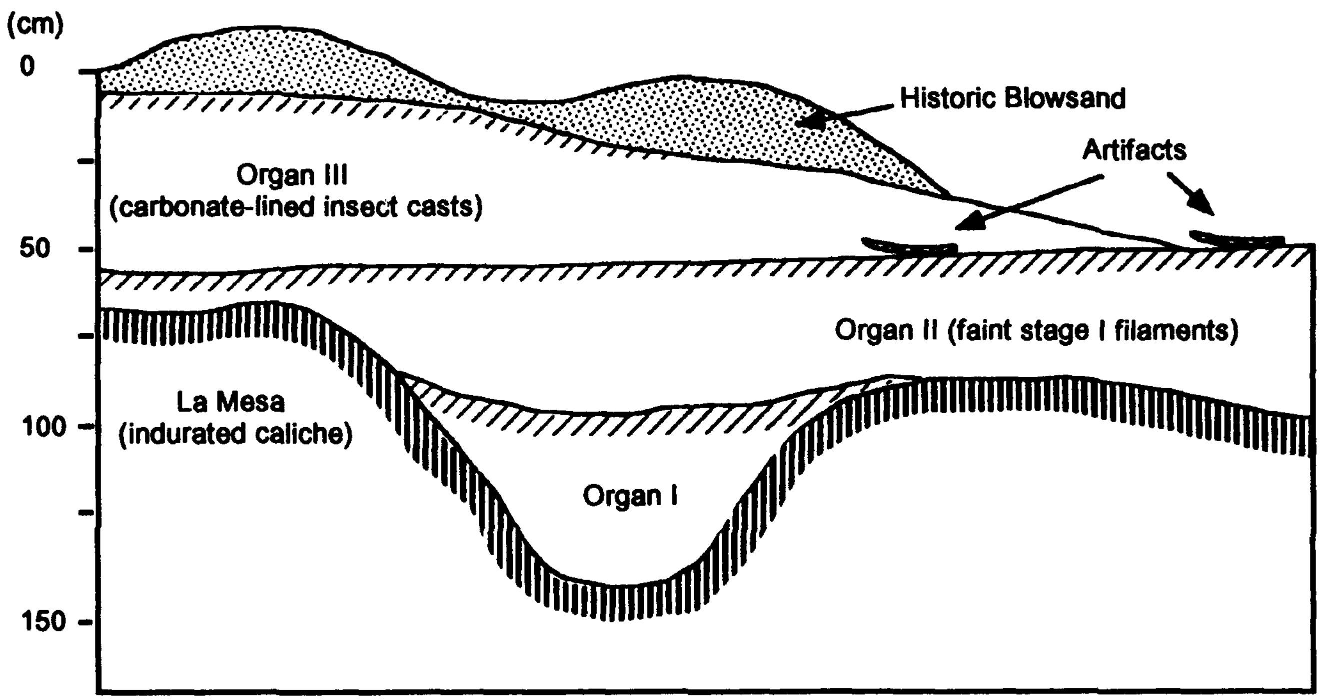


Figure XI-1. Soil Stratigraphy in the Tobin Well Area in the Vicinity of Site 12441

The Tobin Well area, as with much of the basin floor, has experienced various degrees of deflation. Calcrete (indurated caliche) fragments litter some, but not all of the area. These fragments appear to migrate

upward once the caliche comes within a depth of about 40 cm of the surface (see Chapter IV, Mapping Unit 1). The lag deposit described in the previous section was absent in the vicinity of Site 12441.

Radiocarbon dates of carbonate from insect casts in the Organ III deposit at Site 12441 gave a date that was too old: 8590 ±140 B.P. The old age probably resulted because insects used carbonate particles derived from older caliche to construct their casts. The underlying Organ II deposit also gave an older than expected date (5380 ±60 B.P.). This old date is probably also the result of contamination by carbonate particles derived from preexisting caliche. Unlike the 1x1 pit where stage I carbonate needles were carefully separated for dating, a bulk sample was gathered from this site for radiocarbon dating.

McNew Pipeline and State Line Roadcut

The McNew Tank Pipeline

UTM 880858 provides evidence of alternating episodes of erosion-sedimentation followed by landscape stability and soil formation (see Figure XI-2). The stage III and IV caliche indicates an ancient soil of at least Jornada I age (250 to 400 ka, Gile et al. 1981). The caliche is overlain by an argillic horizon with prominent stage I filaments. The question arises as to whether the argillic material is part of the same soil as the caliche or whether it is a younger deposit. In two locations along the profile, C horizon material separates the argillic material from the underlying caliche (see Figure XI-2). Also, a lag accumulation of nodules atop the caliche indicates an episode of deflation that removed the finer friable material. This lag deposit is interpreted to represent the same deflation event that produced the lag deposits in Fort Bliss South. The argillic deposit has prominent stage I filaments that suggest it is of Organ I age. Thus, it appears that an erosional event occurred prior to deposition of Organ I sediments, at approximately 7 ka.

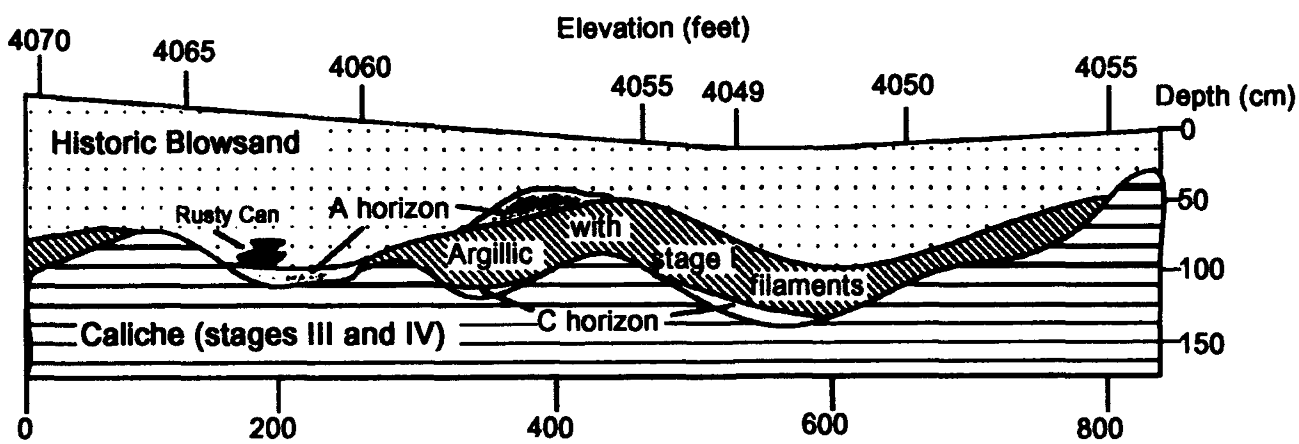


Figure XI-2. Soil Stratigraphy at the McNew Tank Pipeline Trench

Younger Holocene sediments (Organ II and III) are absent this trench, either because they weren't deposited in this area or because they were eroded. An A horizon occurs atop the caliche and is inset against the argillic deposit, indicating it is younger than both. Lying on the A horizon was a rusty can, evidence that

the overlying blowsand is of Historical age. In places, the blowsand is up to 1 m thick. An erosional event apparently removed the A horizon in the majority of the profile prior to the deposition of the historic blowsand

The State Line Roadcut

Most unpaved roads on Fort Bliss lack road cuts. The road along the New Mexico-Texas border, however, expo es subsurface soil strata for several kilometers. In the vicinity of UTM 840410, the road cut exposes the soil buried by Historic blowsand. This feature reveals that the buried land surface is much smoother than the modern hummocky landscape composed of coppice dunes and interdune sheet deposits.

Part III

ARCHAEOLOGICAL IMPLICATIONS AND SUGGESTIONS FOR FUTURE STUDY

Chapter XII

ARCHAEOLOGICAL IMPLICATIONS

Geomorphic Implications of this Study

Holocene alluvium that potentially buries archaeological material occurs in many areas on the fan-piedmont and basin floor landforms (see figures XII-1 and XII-2). Two types of Pleistocene land surfaces have been little affected by wind activity: fan-piedmont areas that are protected by desert pavement, and depressional areas with clayish soils. If these areas were occupied by paleo-Indians, the land surfaces at that time probably appeared much as they do today.

Much of the basin floor, however, has been deflated and reburied by eolian deposits numerous times (see Chapter IV). Minor portions of the basin floor contain exposed deflational surfaces (Mapping Unit 1). In these areas, archaeological visibility is good, but the stratigraphic context probably has collapsed. Most of the basin floor, however, is buried by Historical eolian deposits in the form of dunes and eolian sheet deposits (Mapping Units 2 and 3). Archaeological visibility in these areas is poorer than in the deflational areas; however, these areas are more likely to contain intact archaeological stratigraphy.

There are at least four discrete eolian deposits of Holocene age on the basin floor. Each of these deposits have mappable diagnostic features (see Chapter XI). These deposits appear to coincide with the three generations of Organ alluvium (Organ I, II, III) described by Gile and Hawley (1968) and Gile et al. (1981). Davis and Nials (1988) found three eolian deposits in the Santa Teresa area west of El Paso. They assigned ages of younger than 700 years to the uppermost deposit, 700 to 4,000 years to the middle deposit, and older than 6,000 years to the lowermost deposit.

When archaeological site locations are compared with landform features, the youngest basin fill areas containing clayish soil commonly are the most densely populated (see Figure XII-3). These depressions may have been good water harvesting areas. Also, artifacts are more apparent because many depressional areas have escaped burial by eolian deposits.

Paleoclimatic Implications of this Study

A major shift toward aridity occurred around 8 ka. At this time, the plant community changed from a C-4 dominated grassland toward more C-3 desert scrub vegetation (see chapters VII and IX), erosion increased and produced the Organ alluvial fans (see Chapter XI), and desertification occurred in the basin floor areas producing deflational surfaces, as indicated by lag layers of nodules and pebbles (see Chapter XI). $\delta^{18}O$ values in alluvial-fan soils suggest late Pleistocene temperatures were not drastically cooler than Holocene temperatures (see Chapter VII).

The deflation event that produced the lag layers may have destroyed many paleo-Indian sites. This may, in part, explain why many paleo-Indian artifacts occur as lag material and why intact sites are rare (Jeff Leach, personal communication).

The onset of Organ I deposition, as stated above, probably was in response to the major climate shift that occurred around 8 ka. The onset of Organ II and Organ III, however, may represent smaller climatic fluctuations in the late Holocene. This is one area that needs further investigation (see Chapter XIII).

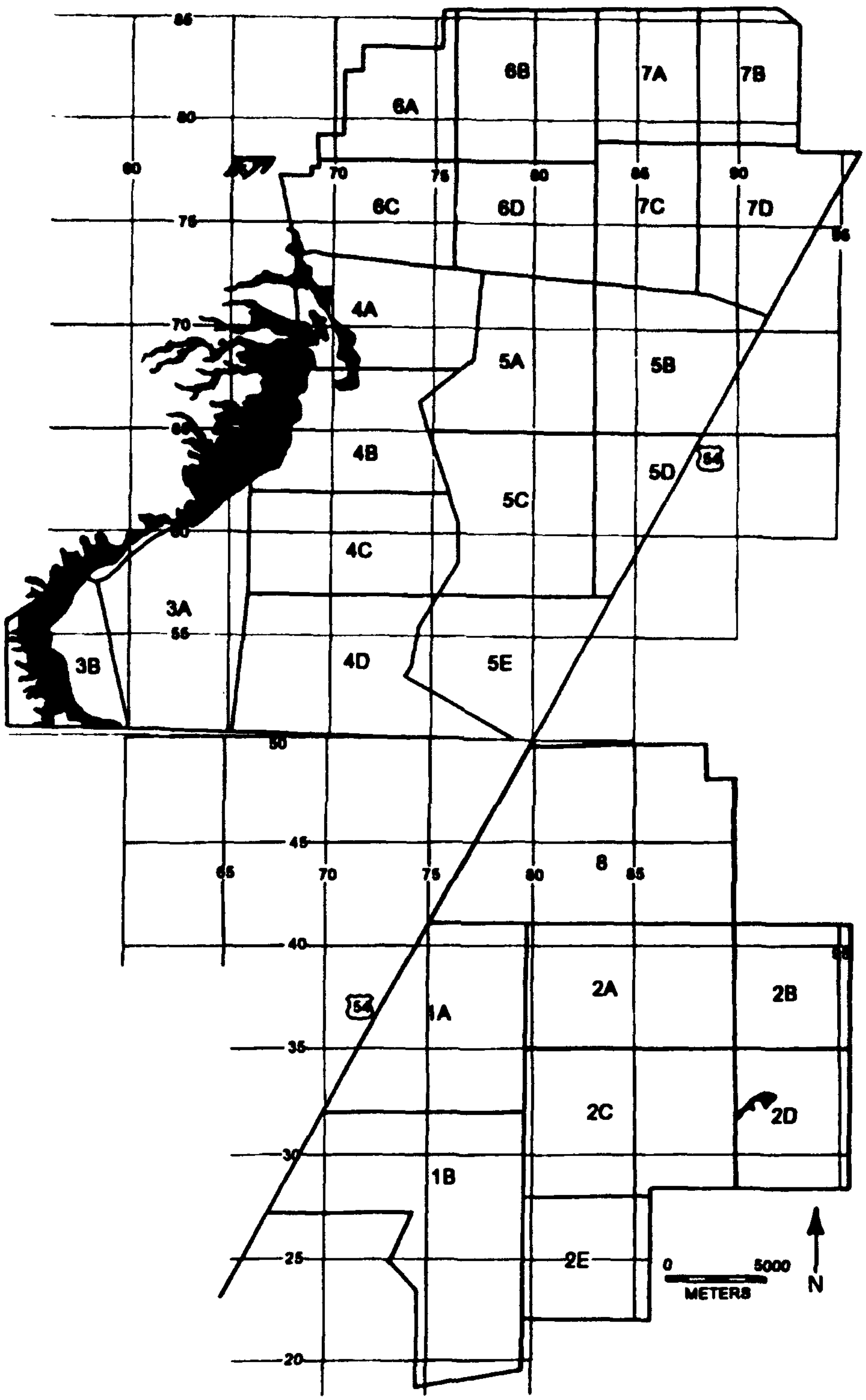


Figure XII-1. Distribution of Organ Fan-piedmont Alluvium (shaded areas) in Fort Bliss Maneuver Areas (Many areas in the basin floor are covered with Organ-age eolian deposits. Organ deposits are less than 7,000 years old and potentially bury many archaeological sites.)

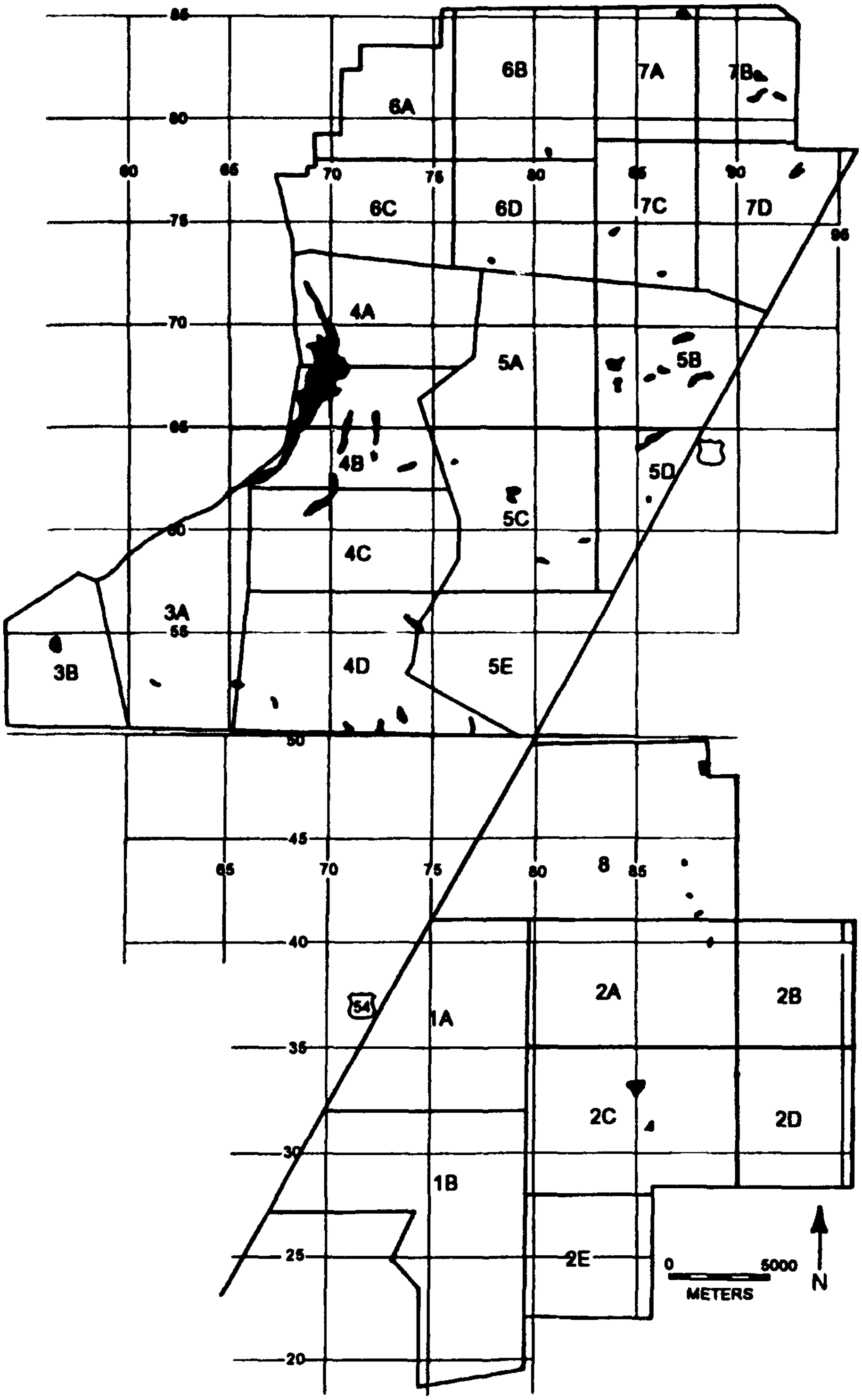


Figure XII-2. Distribution of Lake Tank Alluvium (shaded areas) in Fort Bliss Maneuver Areas (Lake Tank deposits consist mainly of Holocene alluvium in basin floor depressions. As with Organ sediments, these deposits are young enough to contain archaeological material.)

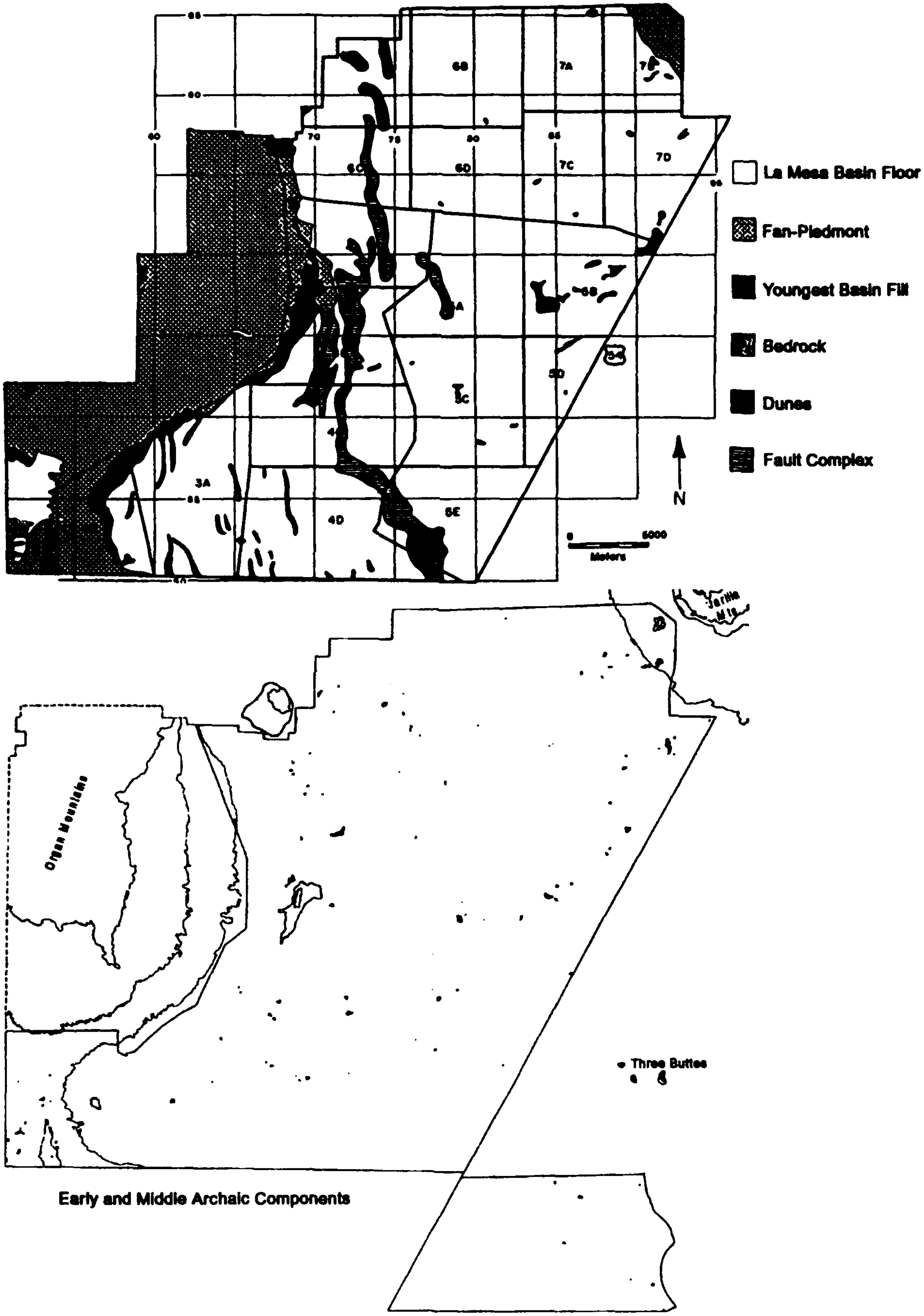


Figure XII-3. A Comparison of Landforms on Fort Bliss North and Early/Middle Archaic Components (Carmichael 1986) (Note the correlation of artifacts and youngest basin fill.)

Chapter XIII

SUGGESTIONS FOR FUTURE STUDY

Several questions surfaced during this project that need further investigation. Of top priority is refining the chronology of Holocene eolian deposits. This will add to our understanding of Holocene environmental conditions and provide an additional method for dating archaeological features. This task can be accomplished through studies involving geomorphologists and archaeologists dating eolian deposits with a combination of radiocarbon organic and inorganic material and archaeological features.

The many fault-trough depression on both Fort Bliss North and South should be targeted for future investigation. These depressions may have the most complete record of eolian deposition because they are good environments for sediment accumulation.

The Old Coe Lake site is a promising area for future paleoenvironmental research. The westward portions of Old Coe Lake may contain pluvial lacustrine sediments buried by alluvial fan deposits. Also, the eastern, leeward side of Old Coe Lake contains multiple eolian deposits that may contain detailed information about periods of aridity. This theory is based on the working model that eolian activity would be greatest during arid periods when the lake was desiccated.

Large dunes in maneuver areas 2B and 5B are encroaching on nondune areas. The movement of these dunes may be a sensitive indicator of aridity.

The multiple generations of alluvial fans apparent on the fan-piedmont areas surrounding the Organ and Franklin Mountains are less apparent in the Hueco Mountains. Owing to smaller watersheds in the Huecos, these deposits are difficult to distinguish on 1:58,000-scale aerial photographs. If maps of geomorphic surfaces are needed to assist archaeologists with chronology studies, then more detailed mapping should be conducted in the Hueco Mountain area.

Backhoe trenching in Maneuver areas 2C and 1B has been helpful for determining subsurface characteristics and their relationship to paleoenvironmental conditions. It is particularly important to connect, with a trench, the 1x1 pit to Trench 7b. It appears that the 1x1 site was a paleodepositional environment for the paleodeflational surface at Trench 7b. A trench connecting the two study sites would prove or disprove that hypothesis.

Although soil-geomorphologic studies have been conducted on McGregor Range (Pigott 1977), detailed geomorphic studies that focus on the ages of soils and sediments may be helpful to Fort Bliss archaeologists.

Appendix A

LABORATORY ANALYSIS AND SOIL PROFILE DESCRIPTIONS

Contained in this appendix are laboratory data and soil profile descriptions for study sites listed in tables I-2 and I-3.

Profile descriptions are for dry soil colors and consistence unless otherwise indicated. Soil textures in profile descriptions are those based on laboratory analysis. Sand fractionation is as follows:

SAND FRACTION	SIZE (mm)
Very Coarse Sand (VCS)	2-1
Coarse Sand (CS)	1-0.5
Medium Sand (MS)	0.5-0.25
180	0.25-0.18
Fine Sand (FS)	0.18-0.10
Very Fine Sand (VFS)	0.10-0.05

The silt category contains particles 0.05 to 0.002 mm in diameter and clay contains particles less than 0.002 mm. Soil morphology description follows procedures in the Soil Survey Manual (Soil Survey Staff, 1981) and soil classification follows *Soil Taxonomy (Soil Survey Staff 1992). Soils buried by more than 50 cm of historical eolian material* were designated by placing an Arabic "2" before the horizon nomenclature.

Soil Profile Description for Eolian Area 1

Soil Classification: Typic Torripsamment
Location: UTM626551
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 19, 1991
Physiography: Basin floor

Dune

- C1: 0-20 cm; strong brown (7.5 YR 4/6) moist; loamy sand; structureless; soft; slightly effervescent; clear boundary.
- C2: 20-65 cm; brown (7.5 YR 5/4), loamy sand; structureless; soft; slightly efferves[illegible] derately alka line; clear boundary.
- 2A: 65-100 cm; brown (7.5 YR 4/3), loamy sand; weak subangular blocky structure; slightly hard; strongly effervescent; abrupt boundary.
- 2Bkm: 100+.

Interdune

- C: 0-13 cm; strong brown (7.5 yr 5/6) moist; sandy loam; structureless; very friable; slightly effervescent.
- 2Bk: 13-46+ cm; light brown (7.5 yr 6/4); weak subangular blocky; slightly hard; effervescent.

Comments

Sparse mesquite dunes with clumps of grasses. Average dune height is approximately 60 cm. Approximately 60 percent of ground is bare. Calcrete fragments on ground. No Bt argillic over Bkm.

Table A-1. Laboratory Data for Eolian Area 1 (dune area)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
DUNE					
C1	0-20	86	3	11	1
C2	20-65	87	1	12	1
2A	65-100	81	8	11	3
2Bkm	100+	74	5	21	17
INTERDUNE					
C	0-13	77	7	16	1
2Bk	13-46+	72	6	22	9

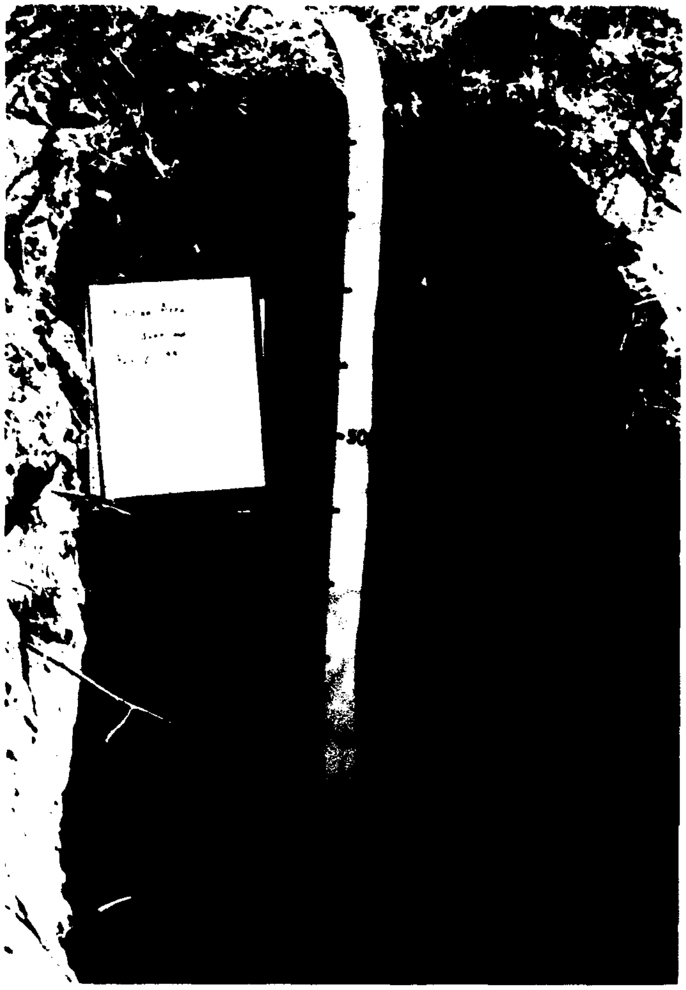


Table A-2. Sand Fractions for Eolian Area 1 (dune area)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
DUNE								
C1	0-20	0	2	12	17	30	22	82
C2	20-65	0	2	18	25	35	10	90
2A	65-100	0	2	17	20	32	15	85
2Bkm	100+	2	5	15	13	22	13	70
INTERDUNE								
C	0-13	0	3	18	20	27	13	82
2Bk	13-46+	2	3	17	18	22	12	73

Soil Profile Description for Eolian Area 2

Soil Classification: Typic Torripsamment
Location: UTM705534
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 19, 1991
Physiography: Basin floor

Dune

- C1: 0-20 cm; strong brown (7.5 YR 4/) moist, loamy sand; structureless; very friable; slightly effervescent.
- C2: 20-160 cm; strong brown (7.5 YR 5/6) moist; loamy sand; structureless; soft.
- 2A: 160-171 cm; brown (7.5 YR 4/4) moist; sandy loam; weak subangular blocky structure; slightly hard.
- 2Btk: 171+ cm; reddish yellow (7.5 YR 6/6) moist; weak subangular blocky structure; slightly hard; Stage I carbonates.

Interdune

- C: 0-3 cm; reddish yellow (7.5 YR 6/6) moist; loamy sand.
- Btk: 3-28 cm; reddish yellow (7.5 YR 6/6) moist; sandy loam.

Comments

Dune height approximately 130 cm. Bare ground approximately 70 percent, more than eolian area 1. No interdune grasses. A very weak argillic.

Table A-3. Laboratory Data for Eolian Area 2 (dune land)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
DUNE					
C1	0-20	86	2	12	2
C2	20-160	87	1	12	1
2A	160-171	80	3	17	10
2Btk	171-200+				
INTERDUNE					
C	0-3	83	5	12	5
Btk	3-28	78	5	17	8

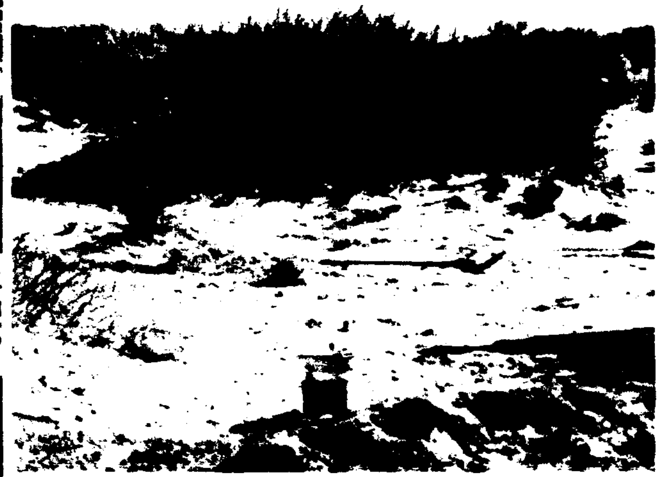


Table A-4. Sand Fractions for Eolian Area 2 (dune land)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
DUNE								
C1	0-20	0	0	10	20	40	15	85
C2	20-160	0	1	18	28	35	8	91
2A	160-171	0	3	25	18	25	8	80
2Btk	171-200+							
INTERDUNE								
C	0-3	0	8	27	15	25	10	85
Btk	3-28	0	5	22	15	23	12	77

Soil Profile Description for Eolian Area 3

Soil Classification: Typic Torripsamments
Location: UTM772521
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 19, 1991
Physiography: Basin floor

Dune

- C1: 0-20 cm; strong brown (7.5 YR 5/6), sandy loam; structureless; soft; noneffervescent.
- C2: 20-48 cm; strong brown (7.5 YR 4/6) moist; loamy sand; structureless; noneffervescent.
- Btk: 48-63+ cm; strong brown (7.5 YR 5/8) moist; sandy loam; weak subangular blocky structure; slightly hard; slightly effervescent; Stage I filaments.

Interdune

- C: 0-14 cm; strong brown (7.5 YR 5/6) moist; sandy loam; structureless; very friable; noneffervescent.
- Btk: 14-36+ cm; yellowish red (5 YR 4/6) moist; sandy loam; structureless; friable, slight effervescent; stage I filaments.

Comments

Coppice dunes, snake weed, yucca. Average dune height is 250 cm. Approximately 50 percent is bare ground. More interdune vegetation than eolian area 2. Very weak argillic in interdune area. Interdune eolian deposits are common but still calcrete fragments on surface.

Table A-5. Laboratory Data for Eolian Area 3 (dune land)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CABONATE (%)
			DUNE		
C1	0-20	80	4	16	1
C2	20-48	85	2	13	2
Btk	48-63+	77	7	16	4
			INTERDUNE		
C	0-14	82	4	14	5
Btk	14-36+	75	7	18	3

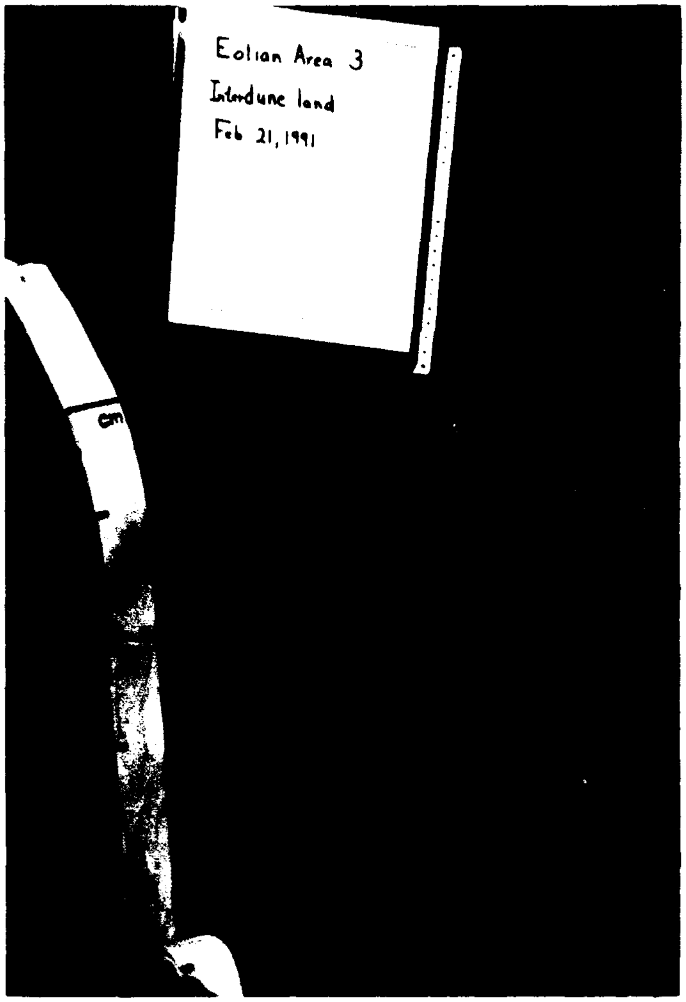


Table A-6. Sand Fractions for Eolian Area 3 (dune land)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
DUNE								
C1	0-20	0	2	12	15	40	15	83
C2	20-48	0	3	27	18	25	15	88
Btk	48-63+	0	3	25	17	23	13	82
INTERDUNE								
C	0-14	0	8	33	17	22	10	90
Btk	14-36+	0	3	25	18	23	10	80

Soil Profile Description for Eolian Area 4

Soil Classification: Typic Torriorthent
Location: UTM845495
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 21, 1991
Physiography: Basin floor

Dune
- C1: 0-20 cm; strong brown (7.5 YR 5/8), sandy loam; structureless; very friable.
- C2: 20-200 cm; strong brown (7.5 YR 5/6), sandy loam; structureless; very friable.
- Btk: 200-230 cm; strong brown (7.5 YR 5/6) moist; sandy loam; weak subangular blocky structure; very friable; Stage I filaments.

Interdune
- C: 0-15 cm; strong brown (7.5 YR 4/6); loamy sand; structureless.
- Btl: 1.5-6.5 cm; yellowish red (5 YR 4/6) moist; sandy loam Bkm 6.5+.

Comments
Mesquite coppice dune area. Average dune height is 225 cm. Approximately 50 percent is bare ground. Calcrete fragments on surface. A very thin Btk Stage I horizon underneath coppice. Approximately 2 m south is a thicker Stage II Btk.

Table A-7. Laboratory Data for Eolian Area 4 (dune land)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
DUNE					
C1	0-20	83	3	14	1
C2	20-200	82	1	17	0
Btk	200-230+	79	2	19	1
INTERDUNE					
C	0-1.5	87	1	12	1
Btk	1.5-6.5	80	2	18	7
Bkm	6.5+				

Table A-8. Sand Fractions for Eolian Area 4 (dune land)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
DUNE								
C1	0-20	0	0	8	22	47	10	87
C2	20-200	0	2	17	25	38	8	90
Btk	200-230+	0	5	25	20	30	8	88
INTERDUNE								
C	0-1.5	0	8	37	18	22	8	93
Btk	1.5-6.5	0	7	27	17	22	8	80
Bkm	6.5+							

Soil Profile Description for Eolian Area 5

Soil Classification: Typic Haplargid
Location: UTM604538
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 21, 1991
Physiography: Basin floor

- A: 0-25 cm; yellowish red (5 YR 4/6) moist, sandy loam; structureless; very friable.
- Btk1: 25-64 cm; strong brown (7.5 YR 5/6) moist, sandy loam; structureless; many very fine.
- Btk2: 64+ cm; Stage III.

Comments
No dunes. Less than 10 percent is bare ground. No calcrete fragments on ground. Weak Bt with Stage I filaments in Btk1 horizon.

Table A-9. Laboratory Data for Eolian Area 5

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
A	0-25	78	9	13	2
Btk1	25-64	71	13	16	8

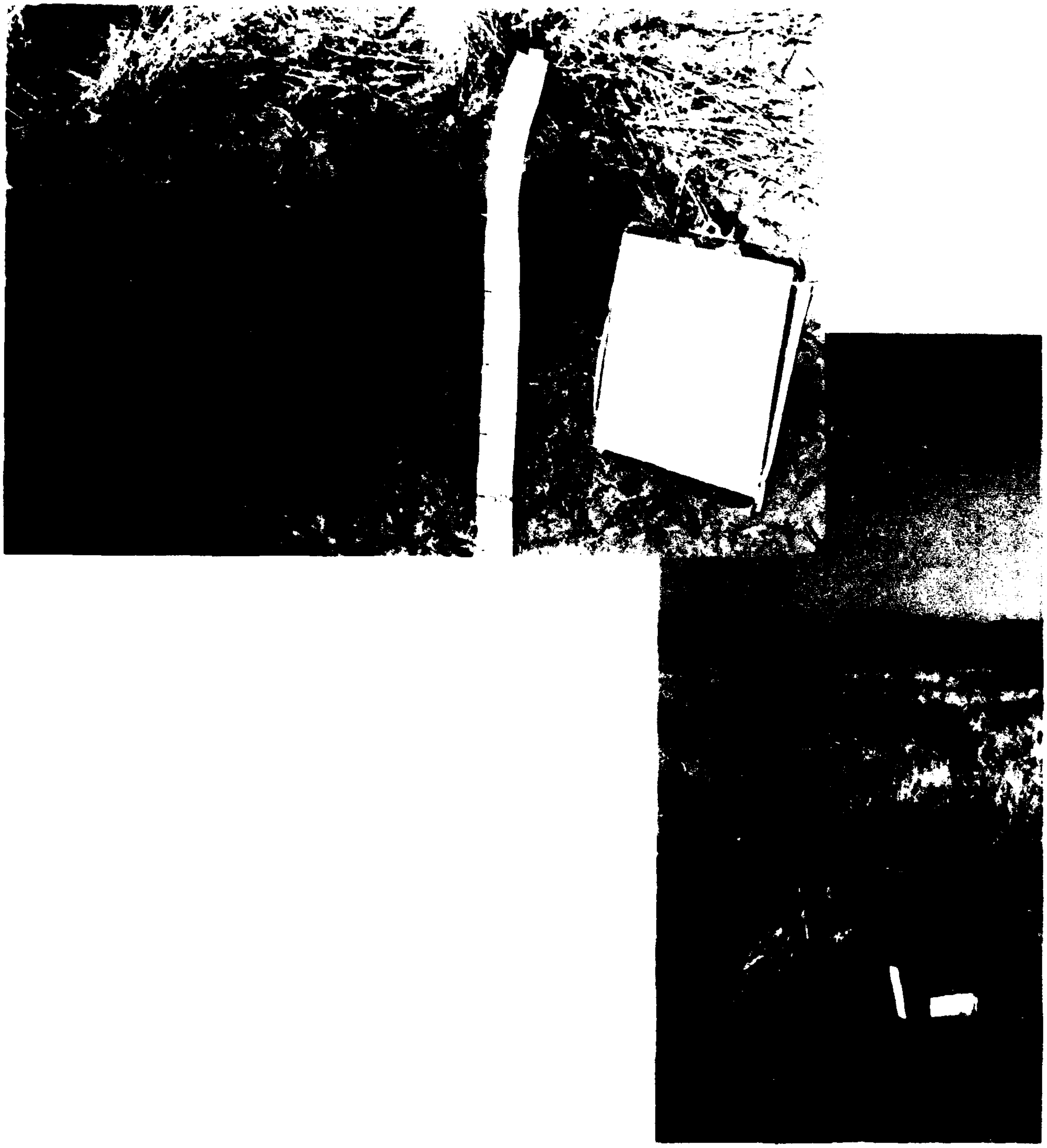


Table A-10. Sand Fractions for Eolian Area 5

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
A	0-25	2	5	17	15	27	13	78
Btk1	25-64	2	7	17	13	23	12	73

Soil Profile Description for Eolian Area 6

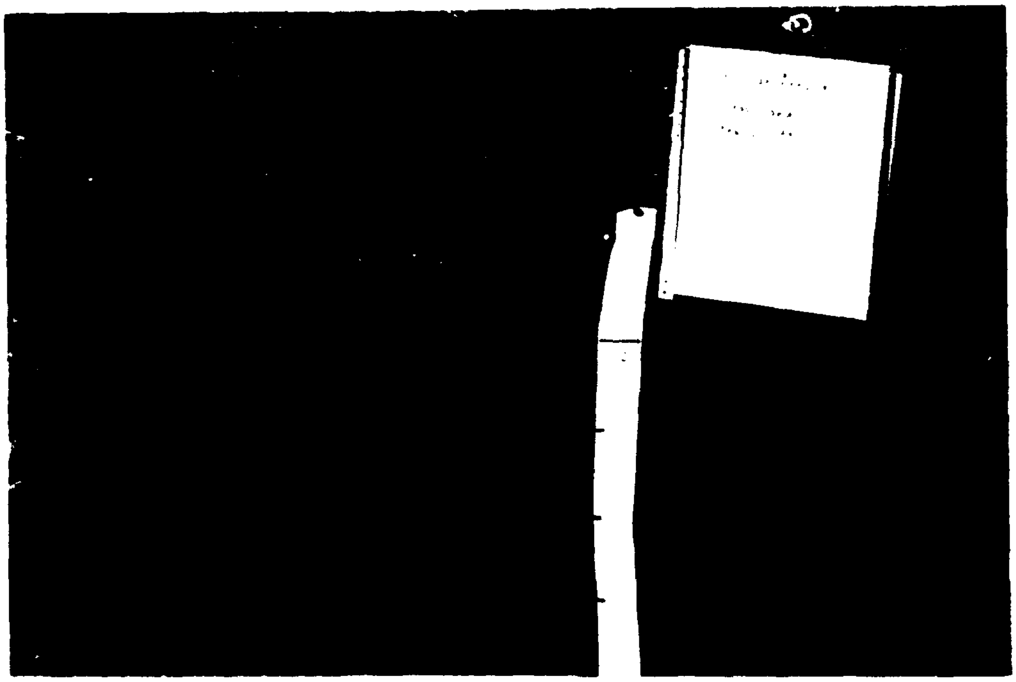
Soil Classification: Typic Torriortent
Location: UTM808493
Parent Material: Basin floor eolian and La Mesa Sediments
Date Described: February 21, 1991
Physiography: Basin floor

- C: 0-5 cm; strong brown (7.5 YR 5/6) moist, loamy sand; structureless; very friable.
- A: 5-20 cm; brown (7.5 YR 4/4) moist, loamy sand; structureless.
- Btk: 20-60+ cm; strong brown (7.5 YR 5/6) moist, sandy loamy; weak subangular blocky.

Comments
No dunes. Less than 5 percent is bare ground. No calcrete fragments on ground. Well developed Btk. Approximately 90 cm to Bkm.

Table A-11. Laboratory Data for Eolian Area 6

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
C	0-5	86	2	12	1
A	5-20	84	2	14	2
Btk	20-60+	76	8	16	7



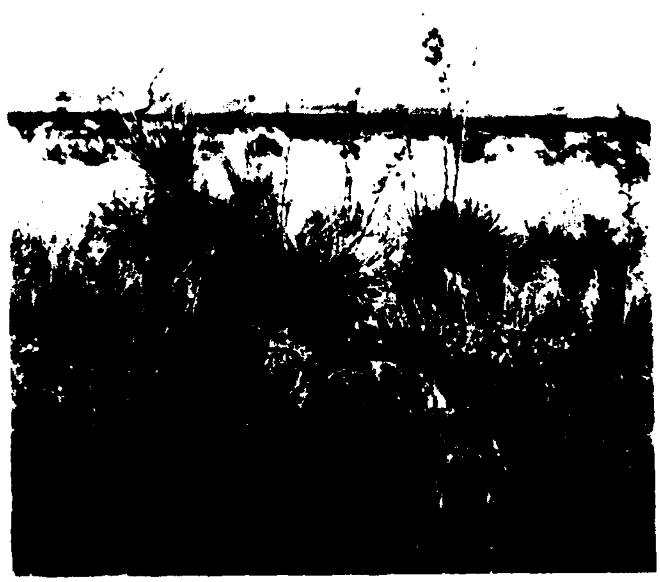


Table A-12. Sand Fractions for Eolian Area 6

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
C	0-5	0	2	20	20	35	12	88
A	5-20	0	3	22	22	32	8	87
Btk	20-60+	0	5	22	15	22	12	75

Soil Profile Description for Eolian Area 7

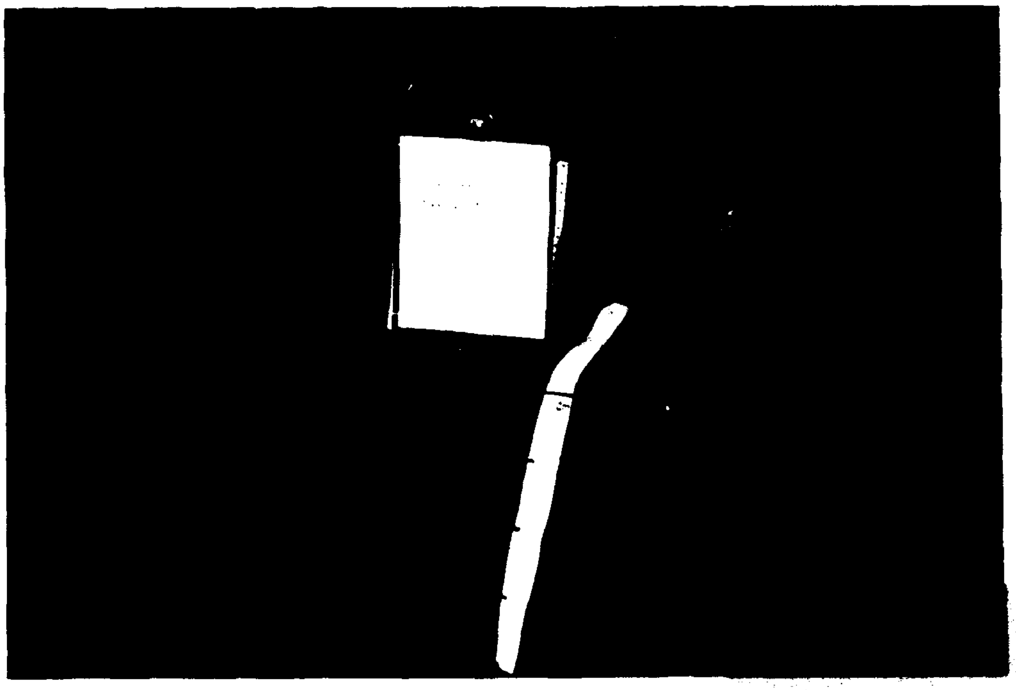
Soil Classification: Typic Haplargid
Location: UTM861544
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 21, 1991
Physiography: Basin floor

- C: 0-20 cm; yellowish red (5 YR 4/6) moist, loamy sand; structureless; soft; many very fine, fine, and medium roots; weakly effervescent; moderately alkaline; clear boundary.
- A: 20-28 cm; reddish brown (5 YR 4/4) moist, sandy loam; structureless; soft; many very fine, fine, and medium roots; slightly effervescent; moderately alkaline
- AB: 28-60 cm; yellowish red (5 YR 4/6) moist, sandy loam; structureless; soft; many very fine, fine, and medium roots; slightly effervescent; moderately alkaline.
- Btk: 60-100 cm; strong brown (7.5 YR 4/6) moist, sandy loam; weak subangular blocky structure; many very fine, fine, and medium roots; slightly effervescent; moderately alkaline.
- Btk: 100+.

Comments
No dunes. Less than 10 percent is bare ground. No calcrete fragments on ground but some on graded road. Btk horizon graded to a horizon with Stage II and III carbonates overlying the petrocalcic, similar to the interdune material at eolian area 4.

Table A-13. Laboratory Data for Eolian Area 7

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
C	0-20	86	2	12	1
A	20-28	80	5	15	1
AB	28-60	80	3	17	2
Btk	60-100	74	6	20	7



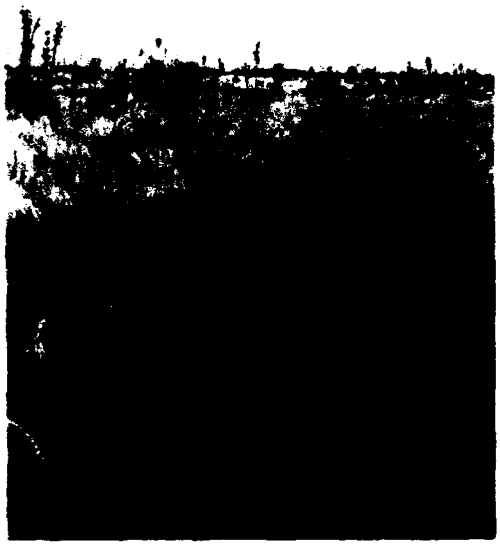


Table A-14. Sand Fractions for Eolian Area 7

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
C	0-20	0	2	3	23	28	10	66
A	20-28	0	3	20	18	32	10	83
AB	28-60	0	3	22	18	28	10	82
Btk	60-100	0	5	20	15	20	12	72

Soil Profile Description for Eolian Area 8

Soil Classification: Typic Haplargid
Location: UTM849675
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 26, 1991
Physiography: Basin floor

- A: 0-20 cm; brown (7.5 YR 5/4), sandy loam; structureless; firm.
- AB: 20-45 cm; brown (7.5 YR 5/4) moist, sandy clay loam; structureless; very firm.
- Btk: 45-50+ cm; strong brown (7.5 YR 5/8), sandy clay loam; weak subangular blocky structure; firm.

Comments
Dunes are smaller than 25 cm. Less than 40 percent is bare ground. No calcrete fragments on ground.

Table A-15. Laboratory Data for Eolian Area 8

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
A	0-20	80	7	13	2
AB	20-45	74	5	21	7
Btk	45-50+	74	6	20	9

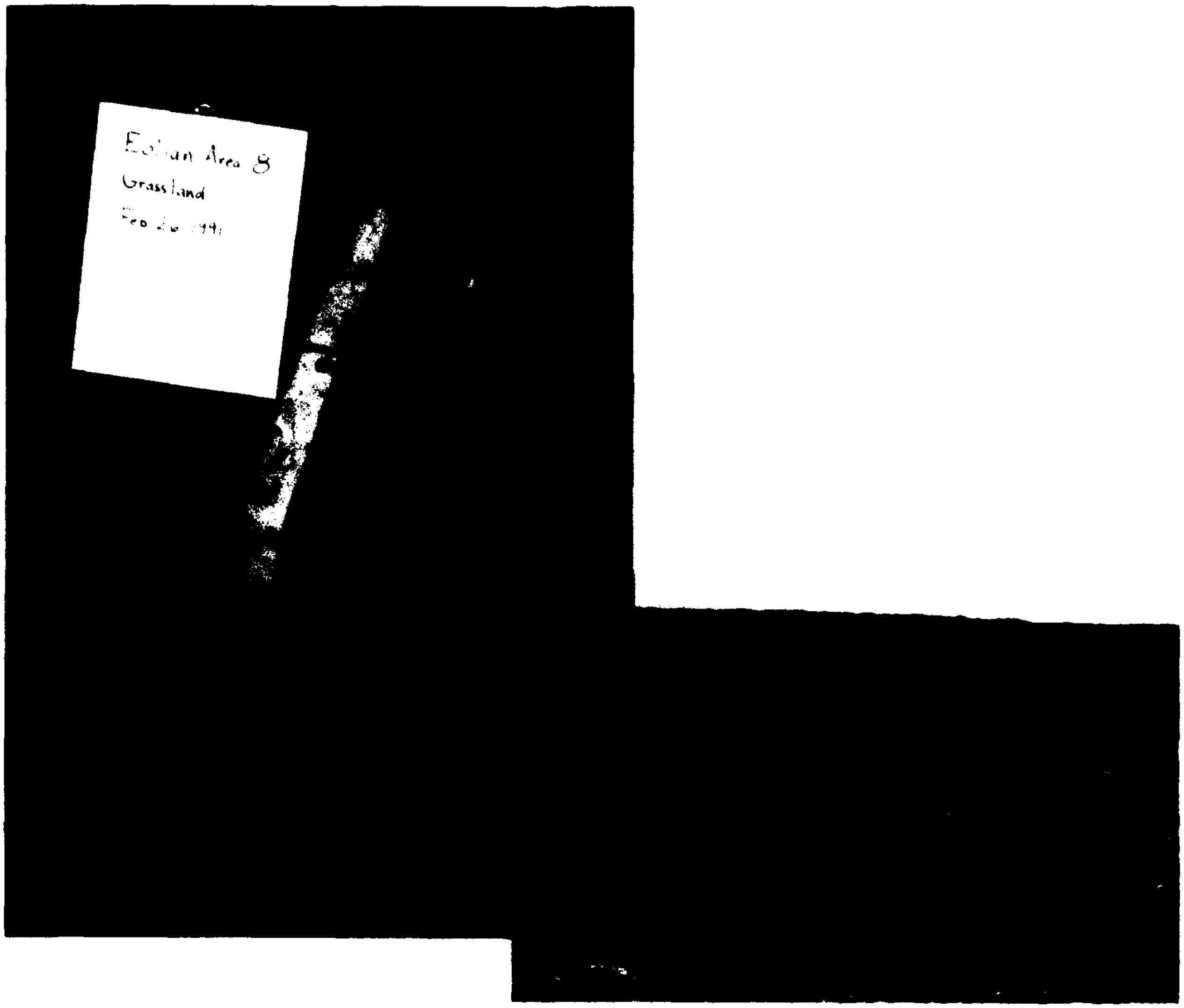


Table A-16. Sand Fractions for Eolian Area 8

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
A	0-20	0	2	13	13	30	22	80
AB	20-45	0	1	15	17	27	12	71
Btk	45-50+	0	2	15	15	23	12	67

Soil Profile Description for Eolian Area 9

Soil Classification: Typic Torripsamments
Location:
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 26, 1991
Physiography: Basin floor

- A: 0-10 cm; reddish brown (5 YR 4/4) moist, sandy loam; structureless; very friable.
- Bw: 10-30 cm; yellowish red (5 YR 4/6) moist, sandy loam; structureless; very friable.
- C: 30-60 cm; strong brown (7.5 YR 5/6) moist, loamy sand; structureless; very friable.

Comments
Dunes absent to 1 m in height. Approximately 30 percent is bare ground. No calcrete fragments on surface.

Table A-17. Laboratory Data for Eolian Area 9

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
A	0-10	82	3	15	1
Bw	10-30	83	2	15	0
C	30-60+	87	1	12	0

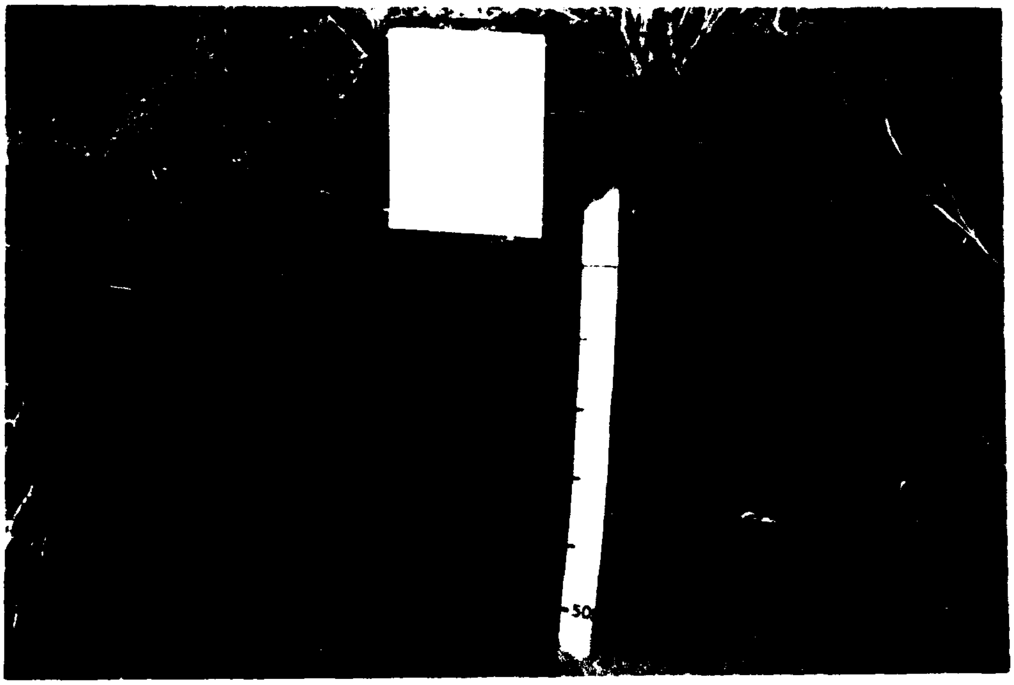


Table A-18. Sand Fractions for Eolian Area 9

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
A	0-10	0	5	32	18	22	10	87
Bw	10-30	0	5	33	20	22	8	88
C	30-60+	0	5	37	25	20	7	93

Soil Profile Description for Eolian Area 10

Soil Classification: Typic Torriortent
Location: UTM831441
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 26, 1991
Physiography: Basin floor

- C: 0-20 cm; strong brown (7.5 YR 5/6), loamy sand; structureless; very friable.
- A: 20-33 cm; yellowish red (5 YR 4/6) moist, sandy loam; structureless; very friable.
- Bt: 33-70 cm; yellowish red (5 YR 4/6) moist, sandy loam; weak subangular blocky structure; friable.
- Btm: 70+.

Comment
No dunes. Less than 25 percent is bare ground. No calcrete fragments. Very weak Bt over petrocalcic. Eolian sheet area.

Table A-19. Laboratory Data for Eolian Area 10

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
C	0-20	86	2	12	2
A	20-33	81	3	16	1
Bt	33-70	79	4	17	1
Bkm	70+				

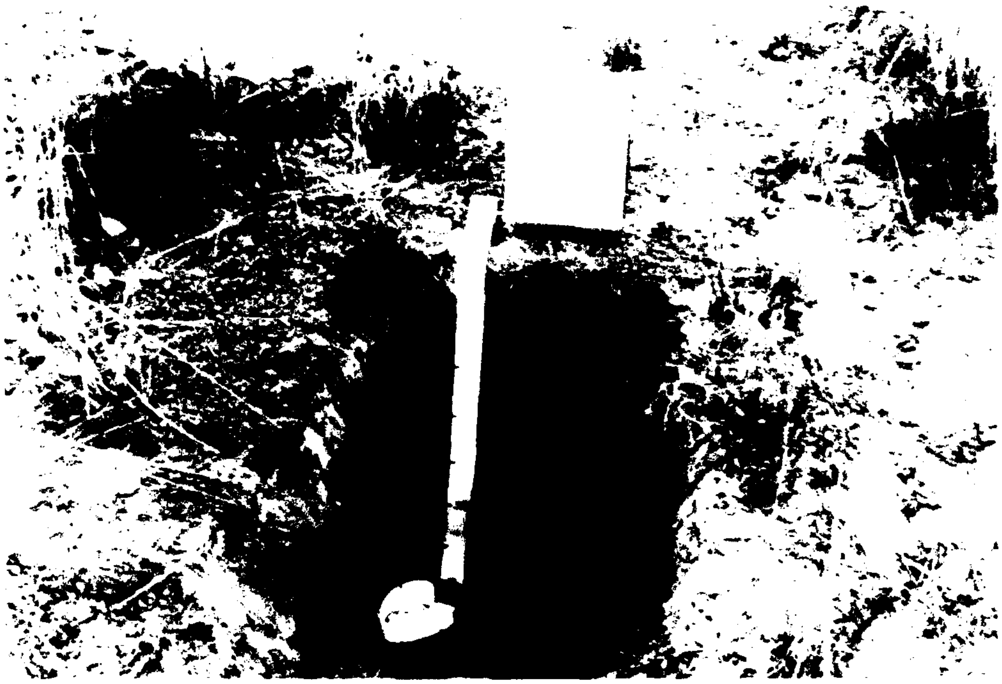


Table A-20. Sand Fractions for Eolian Area 10

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
C	0-20	0	5	37	15	25	8	90
A	20-33	0	3	27	15	28	10	83
Bt	33-70	0	3	25	15	27	10	80
Bkm	70+							

Soil Profile Description for Eolian Area 11

Soil Classification: Typic Haplargid
Location: UTM823385
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 28, 1991
Physiography: Basin floor

- C: 0-43 cm; strong brown (7.5 YR 5/6) moist, loamy sand; structureless; friable.
- A: 43-57 cm; strong brown (7.5 YR 4/6) moist, loamy sand; structureless.
- Btk1: 57-75 cm; strong brown (7.5 YR 5/6) moist, sandy loam; weak subangular blocky structure.
- Btk2: 75-100+ cm; strong brown (7.5 YR 5/6) moist, sandy clay loam; weak subangular blocky structure.

Comments
No dunes. Less than 25 percent is bare ground. No calcrete fragments. Eolian sheet area.

Table A-21. Laboratory Data for Eolian Area 11

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
C	0-43	86	2	12	2
A	43-57	86	2	12	0
Btk1	57-75	79	4	17	7
Btk2	75-100+	73	7	20	13

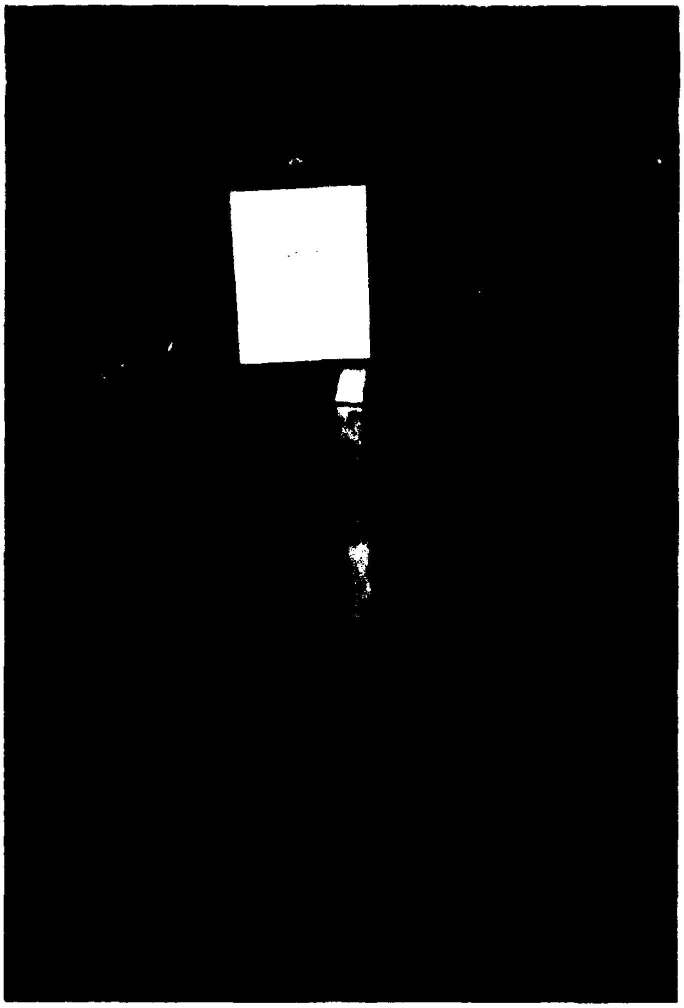


Table A-22. Sand Fractions for Eolian Area 11

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
C	0-43	0	5	33	15	30	10	93
A	43-57	0	3	22	18	40	8	91
Btk1	57-75	0	5	20	12	30	12	78
Btk2	75-100+	1	5	17	10	27	10	69

Soil Profile Description for Eolian Area 12

Soil Classification: Typic Torripsamments
Location: UTM935384
Parent Material: Basin floor eolian and La Mesa sediments
Date Described: February 28, 1991
Physiography: Basin floor

- C: 0-50 cm; strong brown (7.5 YR 5/8) moist, loamy sand; structureless; loose.

Comments
On leeward side of bedrock hill mantled with eolian deposits. Greater than 90 percent bare ground. No calcrete fragments. No Bt.

Table A-23. Laboratory Data for Eolian Area 12

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
C	0-50		87	1	12

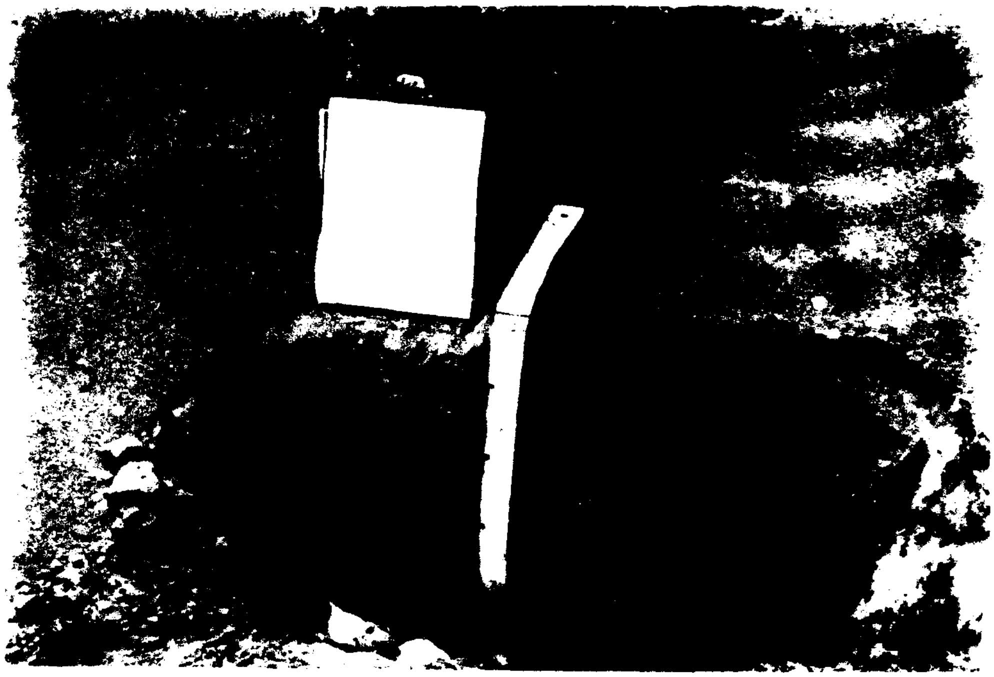


Table A-24. Sand Fractions for Eolian Area 12

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
C	0-50	0	2	33	18	28	8	90

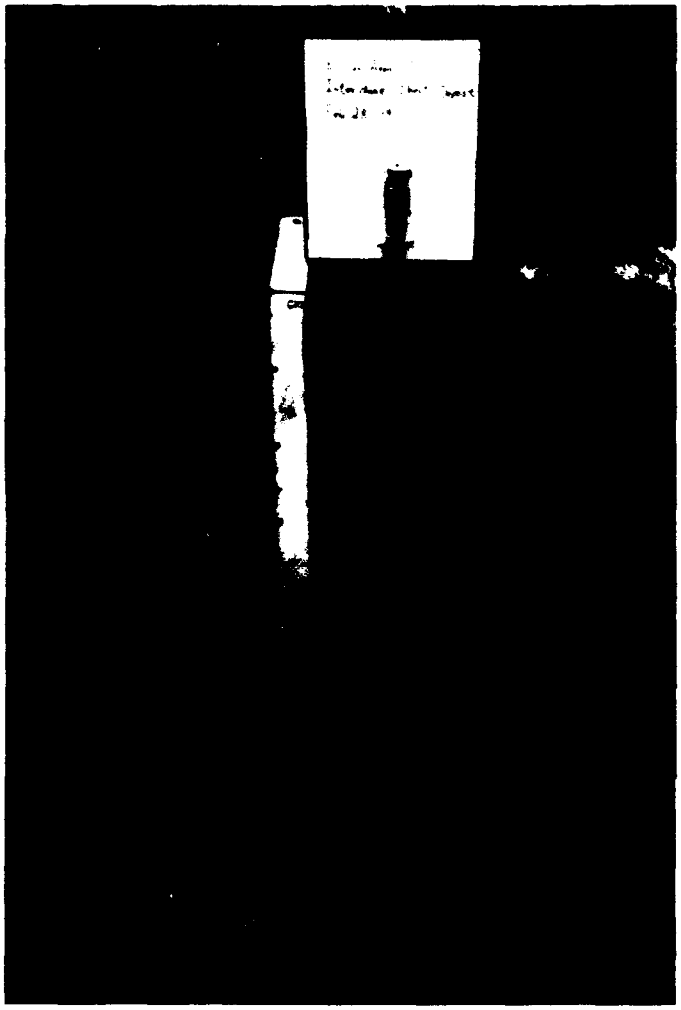
Soil Profile Description for Eolian Area 13

Soil Classification: Torripsamment
Location: UTM809267
Parent Material:
Date Described: February 28, 1991
Physiography:

Comments
Dune height approximately 2 m with interdune sand deposits. Greater than 80 percent bare ground. No calcrete fragments.

Table A-25. Laboratory Data for Eolian Area 13

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	CARBONATE (%)
C	0-40	88	1	11	0
A	40-55	84	4	12	0
C'	55-100+	82	4	14	0



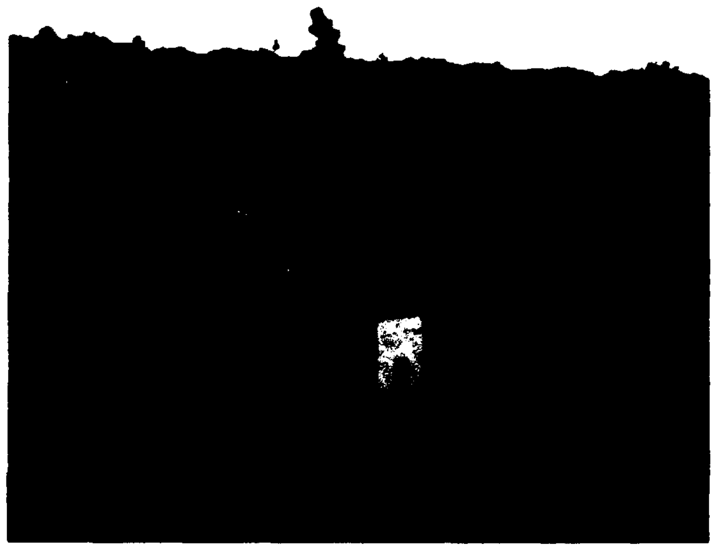


Table A-26. Sand Fractions for Eolian Area 13

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
C	0-40	0	0	7	28	57	5	97
A	40-55	0	2	20	17	42	10	90
C'	55-100+	0	2	22	15	37	12	87

Soil Profile Description for Pedon 90-1

Soil Classification: Typic Camborthid
Location: UTM559574
Parent Material: Organ Mountain alluvial sediment
Date Described: January 7, 1990
Physiography: Organ Mountain fan-piedmont

- E: 0-5; light brown (7.5 YR 6/4) sandy loam; weak, fine platy structure; soft; 23 percent coarse fragment (>2 mm) by volume; clear boundary.
- Bk1: 5-40; light brown (7.5 YR 6/4) sandy loam; moderate, medium subangular blocky structure; soft; 5 percent coarse fragment (>2 mm) by volume; abrupt boundary.
- Bk2: 40-60; pink (7.5 YR 7/3) sandy loam; structureless; loose; 53 percent coarse fragment (>2mm) by volume; abrupt boundary.
- 2Bk: 60-95; brown (7.5 YR 5/4) sandy loam; weak subangular blocky structure; loose; 23 percent coarse fragment (>2mm) by volume; gradual boundary.
- 2C: 95-110; light brown (7.5 YR 6/4) sandy loam; structureless; loose; 30 percent coarse fragment (>2mm) by volume; gradual boundary.
- 3Bk: 110-150; reddish brown (7.5 YR 6/6) sandy loam; moderate subangular blocky structure; slightly hard; 20 percent coarse fragment (>2mm) by volume; abrupt boundary.
- 3C: 150-190; pink (7.5 YR 7/4) sandy loam; structureless; loose; moderately effervescent; 55 percent coarse fragment (>2mm) by volume; moderately alkaline; abrupt boundary.
- 4Btk: 190-210; yellowish red (5 YR 5/6) sandy loam; strong subangular blocky structure; hard; 10 percent coarse fragment (>2mm) by volume; clear boundary.
- 4Bkm: 210-300; pinkish white (7.5 YR 8/2) sandy loam; massive; very hard; 60 percent coarse fragment (>2mm) by volume; gradual boundary.
- 4Bk: 300+; pink (7.5 YR 7/3) sandy loam; structureless; slightly hard; 60 percent coarse fragment (>2mm) by volume.

Table A-27. Laboratory Data for Pedon 90-1 (Organ over Jornada II)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
ORGAN III							
E	0-5	75	11	14	23	1	0.29
Bk1	5-40	74	11	15	5	6	0.47
Bk2	40-60	79	6	15	53	6	0.49
ORGAN II							
2Bk	60-95	75	11	14	23	6	0.21
2C	95-110	76	10	14	30	3	0.45
ORGAN I							
3Bk	110-150	72	12	16	20	4	0.27
3C	150-190	73	14	13	55	3	0.39

Table A-27, continued

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
JORNADA II							
4Btk	190-210	59	23	18	10	5	0.33
4Bkm	210-300	65	20	15	70	25	0.35
4Bk	300+	78	10	12	60	22	0.18

Table A-28. Sand Fractions for Pedon 90-1

SAMPLE NO.	VCS (gm)	CS (gm)	MS (gm)	180 (gm)	FS (gm)	VFS (gm)	TOTAL SAND (gm)	SAND (%)
E	2.3	2.6	4.7	4.7	14.1	9.2	37.4	75.2
BK1	2.6	3.8	4.7	4.1	12.1	8.7	35.9	72.2
BK2	4.5	5.6	8.2	5.0	10.3	7.2	40.8	81.9
2BK	2.3	3.1	4.8	3.9	12.7	10.0	36.8	74.3
2C	9.2	7.6	6.0	3.0	6.2	6.0	37.9	76.5
3BK	3.2	4.0	5.4	3.8	10.4	8.5	35.3	70.9
3C	6.4	5.8	5.6	3.5	8.0	6.9	36.3	73.5
4BTK	1.3	3.7	5.3	3.2	7.5	8.1	29.2	58.6
4BKm	5.2	3.8	4.6	7.6	6.3	6.1	33.7	68.2
4BK	6.6	5.7	7.2	4.2	7.8	5.7	37.2	74.8

Soil Profile Description for Pedon 90-2

Soil Classification: Fluventic Camborthid
Location: UTM565571
Parent Material: Organ Mountain alluvial sediment
Date Described: December 14, 1990
Physiography: Organ Mountain fan-piedmont

- E: 0-10 cm; light brown (7.5 YR 6/4) sandy loam; moderate subangular blocky structure; soft; 4 percent coarse fragment (>2mm) by volume; moderately alkaline; clear boundary.
- Bk: 10-80 cm; light brown (7.5 YR 6/4) sandy loam; moderate, medium subangular blocky structure; soft; 2 percent coarse fragment (>2 mm) by volume; moderately alkaline; diffused boundary.
- C: 80-170 cm; light brown (7.5 YR 6/4) sandy loam; structureless; soft; 1 percent coarse fragment (>2mm) by volume; clear boundary.
- 2Bk: 170-215 cm; reddish yellow (5 YR 6/6) sandy loam; moderate subangular blocky structure; slightly hard to soft; 3 percent coarse fragment (>2mm) by volume; clear boundary.
- 2C: 215-245 cm; reddish yellow (5 YR 6/6) loamy sand; weak subangular blocky structure; soft; 25 percent coarse fragment (>2mm) by volume; clear boundary.
- 3Bk: 245-265 cm; reddish brown (5 YR 6/6) sandy loam; moderate subangular blocky structure; soft; 26 percent coarse fragment (>2mm) by volume; clear boundary.
- 3C: 265-315 cm; reddish brown (5 YR 6/6) sandy loam; structureless; soft; 24 percent coarse fragment (>2mm) by volume; abrupt boundary.
- 4Btk: 315+ cm; yellowish red (5 YR 5/6) sandy loam; strong subangular blocky structure; hard; 5 percent coarse fragment (>2mm) by volume.

Table A-29. Laboratory Data for Pedon 90-2 (Organ over Jornada II)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
ORGAN III							
E	0-10	75	11	14	4	5	0
Bk	10-80	73	11	16	2	3	1
C	80-170	77	5	18	1	4	0
ORGAN II							
2Bk	170-215	72	11	17	3	4	0
2C	215-245	82	5	13	25	6	0
ORGAN I							
3Bk	245-265	79	5	16	26	7	0
3C	265-315	78	12	10	24	8	0
JORNADA II							
4Btk	315+	68	5	27	5	5	0

Table A-30. Sand Fractions for Pedon 90-2

SAMPLE NO.	VCS (gm)	CS (gm)	MS (gm)	180 (gm)	FS (gm)	VFS (gm)	TOTAL SAND (gm)	SAND (%)
E	0.9	3.1	5.9	4.5	15	12.9	42.4	74.3
BK1	3.2	3.9	6.2	4.7	13.6	10.2	41.8	73.3
C	8.1	11.6	10.5	4.6	9.6	6.2	50.7	88.9
2BK	0.6	1.7	4.4	4.5	17	12.4	40.6	71.3
2C	0.9	2.9	7.4	7.4	20.2	10.5	49.3	86.5
3BK	0.9	2	3.9	3.6	10.6	8.7	29.7	52.1
3C	4.1	9.7	16.4	8.8	12.2	4	55.2	96.8
4BTK	1.1	3.9	5.8	3.2	7.7	8.2	30	52.6

Soil Profile Description for Pedon 90-3

Soil Classification: Typic Camborthid
Location: UTM568566
Parent Material: Organ Mountain alluvial sediment
Date Described: January 1991
Physiography: Organ Mountain fan-piedmont

- C1: 0-5 cm; light brown (7.5 YR 6/4) sandy loam; platy structure; loose; abrupt boundary.
- Bk: 5-90 cm; light brown (7.5 YR 6/4) sandy clay loam; weak subangular blocky structure; soft; abrupt boundary.
- 2Ak: 90-140 cm; light brown (7.5 YR 6/3) silt loam; moderate prismatic structure; slightly hard; clear boundary.
- 2Btk: 140-200 cm; reddish yellow (7.5 YR 6/6) clay loam; moderate prismatic structure; hard; moderately effervescent; 4 percent coarse fragment (>2mm) by volume; moderately alkaline; clear boundary.
- 3Btk: 200-225 cm; yellowish red (5 YR 5/6) clay; strong prismatic structure; very hard; clear boundary.
- 3Bk: 225+ cm; pink (7.5 YR 8/3) sandy clay loam; weak subangular blocky structure; extremely hard.

Table A-31. Laboratory Data for Pedon 90-3 (Organ over Jornada II)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
ORGAN							
C	0-5	82	5	13	1	3	0
Bk	5-90	60	4	36	4	7	1
2Ak	90-140	13	61	26	0	15	1
2Btk	140-200	39	25	36	4	7	0
JORNADA II							
3Btk	200-225	39	12	49	5	4	1
3Bk	225+	53	17	30	13	16	1

Table A-32. Sand Fractions for Pedon 90-3

SAMPLE NO.	VCS (gm)	CS (gm)	MS (gm)	180 (gm)	FS (gm)	VFS (gm)	TOTAL SAND (gm)	SAND (%)
C	1.1	11.3	12.7	6.8	12.6	7.9	52.4	88.9
Bt	1	2.6	4.5	3.5	13.3	12.2	14	25.0
2Ak	0	0.1	0.4	0.4	1.7	6.7	23.8	52.2
2Btk	0.3	1.2	2.4	2.1	7.2	9.6	24	42.6
3Btk	0.6	1.9	3.8	2.9	7.3	6.8	29.5	49.8
3Bk	0.2	0.7	2.8	4.8	21.8	13.2	17	32.7

Soil Profile Description for Pedon 90-4

Soil Classification: Ustollic Haplargid
Location: UTM564555
Parent Material: Basin floor alluvium
Date Described: January 1991
Physiography: Basin floor depression

- A: 0-15 cm; pale brown (10 YR 6/3) silt loam; platy structure; slightly hard; clear boundary.
- Btk1: 15-80 cm; brown (7.5 YR 5/4) sandy clay; moderate prismatic structure; hard; gradual boundary.
- Btk2: 80-200 cm; strong brown (7.5 YR 5/6) sandy clay loam; weak prismatic structure; slightly hard; clear boundary.
- Bk1: 200-240 cm; pinkish white (7.5 YR 8/2) sandy clay loam; weak subangular blocky structure; extremely hard to loose; gradual boundary.
- Bk2: 240+ cm; light brown (7.5 YR 6/4) sandy clay loam; moderate subangular blocky structure; very hard; moderately alkaline.

Table A-33. Laboratory Data for Pedon 90-4 (Petts Tank, Qbf.)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
A	0-15	25	48	27	0	8	1
Btk1	15-80	49	7	44	0	9	1
Btk2	80-200	63	16	21	3	4	0
Bk1	200-240	50	18	32	1	43	0
Bk2	240+	64	13	23	9	16	0

Table A-34. Sand Fractions for Pedon 90-4

SAMPLE NO.	VCS (gm)	CS (gm)	MS (gm)	180 (gm)	FS (gm)	VFS (gm)	TOTAL SAND (gm)	SAND (%)
A	0	0.2	0.6	1	5.5	9.9	17.2	32.7
Btk1	0	0.4	1.8	2.4	10.7	11.2	26.4	46.3
Btk2	0.4	2.3	6.9	6	13.5	8.9	38	67.1
Bk1	0.7	1.5	3.8	3.2	7.5	6.4	23	52.3
Bk2	0.8	1.6	4.5	4.4	13.8	10.9	36	63.2

Soil Profile Description for Pedon 90-5

Soil Classification: Typic Haplotorrert
Location: UTM565545
Parent Material: Basin floor alluvium
Date Described: January 1991
Physiography: Basin floor depression

- A: 0-15 cm; dark grayish brown (10 YR 4/2) silty clay; moderate granular structure; soft; gradual boundary.
- C: 15-215 cm; brown (7.5 YR 5/3) clay; strong angular blocky structure; extremely hard; clear boundary.
- 2Btk: 215-270 cm; strong brown (7.5 YR 5/6) sandy clay loam; weak subangular blocky structure; very hard.

Table A-35. Laboratory Data for Pedon 90-5 (Lake Tank, Q1)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
A	0-15	3	40	57	1	12	1
C	15-215	4	33	63	2	11	1
2Btk	215-270+	55	19	26	0	4	0

Table A-36. Sand Fractions for Pedon 90-5

SAMPLE NO.	VCS (gm)	CS (gm)	MS (gm)	180 (gm)	FS (gm)	VFS (gm)	TOTAL SAND (gm)	SAND (%)
A	0	0.3	0.6	0.5	1	1.5	3.9	7.4
C	0.1	0.5	0.9	0.7	1.3	1.6	5.1	9.2
2Btk	0.1	2	8.5	7.3	11.1	6.3	35.2	61.0

Soil Profile Description for Pedon 91-1

Soil Classification: Typic Calciorthid
Location: UTM641634
Parent Material: Organ Mountain alluvial sediment
Date Described: May 14, 1991
Physiography: Organ Mountain fan-piedmont

- C: 0-2 cm; pale brown (10 YR 6/3) sandy loam; structureless; loose; many very fine, fine, and medium roots; slightly effervescent; 1 percent coarse fragment (>2mm) by volume; moderately alkaline; clear boundary.
- Bk: 2-30 cm; pale brown (10 YR 6/3) sandy loam; structureless to platy; hard to slightly hard
- C': 30-147 cm; pale brown (10 YR 6/3) sandy loam; structureless; slightly hard.
- 2Btk: 147-165 cm; brown (7.5 YR 5/4) sandy loam; weak subangular blocky structure; slightly hard.
- 2Bk: 165-190 cm; brown-pinkish white (7.5 YR 5/4-8/2) sandy loam; strong subangular blocky structure; hard.
- 3Btk1: 190-225 cm; yellowish red (5 YR 5/6) sandy loam; strong prismatic; very hard.
- 3Btk2: 225-290 cm; brown-pinkish white (7.5 YR 5/4-8/2) sandy loam; weak subangular blocky; very hard.
- 3Bk: 290-320+ cm; yellowish brown (5 YR 5/4) sandy loam; moderate subangular blocky structure; slightly hard.

Table A-37. Laboratory Data for Pedon 91-1 (Organ/Isaacks'/Jornada II)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
				ORGAN			
C	0-2	84	6	10	1	1.4	0.25
Bk	2-30	77	7	16	1	9.6	0.6
C'	30-147	80	3	17	2	3.8	0.12
				ISAACK'S RANCH			
2Btk	147-165	79	1	20	12	6.4	0.26
2Bk	165-190	87	1	12	23	17	0.2
				JORNADA II			
3Btk1	190-225	53	27	20	17	12	0.25
3Btk2	225-290	81	3	16	13	19.1	0.1
3Bk	290-320	77	6	17	13	9.4	0.20

Table A-38. Sand Fractions for Pedon 91-1 (Organ/Isaacks'/Jornada III)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)
			ORGAN				
C	0-2	0.7	4.9	18.3	9.8	10.8	5.9
Bk	2-30	0.5	3.6	15.3	8.5	11.3	6.6
C'	30-147	0.1	0.1	3.2	18.1	27.1	2.7

Table A-38, continued

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)
ISAACK'S RANCH							
2Btk	147-165	0.5	8.5	17.3	8.1	9.1	4.8
2Bk	165-190	0.6	5.2	24	11	9.7	3.5
JORNADA II							
3Btk1	190-225	0.6	3.5	9.8	4.8	6.4	4.4
3Btk2	225-290	2.4	19.3	15.5	6.4	6.4	3
3Bk	290-320	3.2	6	16.4	7.3	7.6	4.3

Soil Profile Description for Pedon 91-2 (Organ over Jornada II)

Location: UTM648644

HORIZON	DEPTH (cm)	ALLUVIUM
A	0-5	Organ
Bw	5-30	Organ
C	30-125	Organ
2Bk1	125-200	Organ
2Bk2	200-280	Organ
3Btk	280-300+	Jornada II

Soil Profile Description for Pedon 91-3

Soil Classification: Typic Paleorthid
Location: UTM654649
Parent Material: Organ Mountain alluvial sediment
Date Described: May 14, 1991
Physiography: Organ Mountain fan-piedmont

- A: 0-25 cm; brown (7.5 YR 5/4) sandy loam; structureless; loose.
- Bk: 25-40 cm; brown (7.5 YR 5/4) sandy loam; moderate subangular blocky structure; slightly hard.
- Bkm: 40-70 cm; pinkish white (7.5 YR 8/2) sandy clay loam; massive and platy structure; very hard.
- Bk1: 70-140 cm; pinkish white (7.5 YR 8/2) sandy clay loam; weak subangular blocky structure; slightly hard to hard.
- Bk2: 140-300+ cm; pink (7.5 YR 7/3) sandy loam; weak subangular blocky structure; slightly hard to hard.

Table A-39. Laboratory Data for Pedon 91-3 (La Mesa)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
A	0-25	76	9	15	13	1	0.3
Bk	25-40	81	3	16	63	9	0.57
Bkm	40-70	78	1	21	24	55	0.11
Bk1	70-140	66	4	30	31	35	0.2
Bk2	140-300	80	8	12	21	7	0.23

Table A-40. Sand Fractions for Pedon 91-3 (La Mesa)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)
A	0-25	1	5	11	6	6	3
Bk	25-40	10	9	11	5	5	3
Bkm	40-70	11	10	10	4	4	2
Bk1	70-140	1	3	9	6	6	4
Bk2	140-300	3	6	18	10	8	2

Soil Profile Description for Pedon 91-4

Soil Classification: Haplargid
Location: UTM688659
Parent Material: Basin floor alluvium
Date Described: May 14, 1991
Physiography: Basin floor depression

- A: 0-18 cm; pale brown (10 YR 6/3) clay loam; strong subangular blocky to platy structure; hard.
- Ak: 18-30 cm; dark yellowish brown (10 YR 4/3) sandy loam; moderate subangular blocky structure; soft.
- Btk: 30-90 cm; brown (10 YR 4/3) sandy clay loam; strong, prismatic structure; very hard.
- Cgk1: 90-140 cm; light brown (7.5 YR 6/4) sandy loam; structureless; soft.
- Bgk1: 140-190 cm; light brown (7.5 YR 6/4), pinkish white (7.5 YR 6/4) sandy loam; weak subangular blocky structure; slightly hard to hard.
- Bgk2: 190-250 cm; pinkish white (7.5 YR 8/2) sandy clay loam; moderately subangular blocky structure; very hard.
- Bgk3: 250-330+ cm; white (10 YR 8/2), strong brown (7.5 YR 5/8) sandy clay loam; weak subangular blocky structure; hard.

Table A-41. Laboratory Data for Pedon 91-4 (Lake Tank)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
A	0-18	40	27	33		7.5	0.5
Ak	18-30	72	16	12		5.2	0.72
Btk	30-90	55	10	35		4.5	0.22
Cgk	90-140	78	11	11		0.2	0.13
Bgk1	140-190	68	17	15		4.4	0.05
Bgk2	190-250	66	4	30	21	45.2	0.08
Bgk3	250-330	75	3	22	27	37.7	0.02

Table A-42. Sand Fractions for Pedon 91-4 (Lake Tank)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)
A	0-18	0	0	1	1	5	10
Ak	18-30	0	6	19	8	7	4
Btk	30-90	0	2	9	7	8	6
Cgk	90-140						
Bgk1	140-190	0	3	18	9	6	3
Bgk2	190-250	1	3	10	6	7	4
Bgk3	250-330	1	6	17	7	7	4

Soil Profile Description for Pedon 91-5

Soil Classification: Typic Haplargid
Location: UTM703660
Parent Material: Basin floor camp rice alluvium
Date Described: May 14, 1991
Physiography: La Mesa Basin floor

- C: 0-5 cm; brown (7.5 YR 5/4) sandy loam; structureless; loose.
- Bk1: 5-40 cm; light brown (7.5 YR 6/4) sandy loam; very coarse and moderate subangular blocky structure; slightly hard; slightly effervescent.
- Bk2: 40-70 cm; light brown (7.5 YR 6/4), pinkish white (7.5 YR 8/2) sandy clay loam; medium moderate subangular blocky structure; slightly hard; violently effervescent.
- Btk: 70-100 cm; strong brown (7.5 YR 5/6), pinkish white (7.5 YR 8/2) sandy clay loam; medium moderate subangular blocky structure; hard; violently effervescent.
- Bkm: 100-180 cm; pink (7.5 YR 7/3), pinkish white (7.5 YR 8/2) sandy clay loam; medium moderate subangular blocky structure; very hard; violently effervescent.
- Bk: 180-280 cm; pink (7.5 YR 8/3) sandy loam; fine moderate subangular blocky structure; soft; violently effervescent.
- C: 280-330+ cm; sandy loam.

Table A-43. Laboratory Data for Pedon 91-5 (La Mesa)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
C	0-5	80	6	14	1	0.2	0.2
Bk1	5-40	79	5	16		4.5	0.15
Bk2	40-70	74	2	24	12	23.9	0.1
Btk	70-100	54	11	35	13	14.6	0.08
Bkm	100-180	69	10	21	18	42.8	0.1
Bk	180-280	71	14	15	14	12.8	0.02
C	280-330	78	7	15		0.5	0.20

Table A-44. Sand Fractions for Pedon 91-5 (La Mesa)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)
C	0-5	0	3	17	8	9	4
Bk1	5-40	1	4	7	3	6	7
Bk2	40-70	1	5	14	7	8	5
Btk	70-100	0	5	15	8	9	4
Bkm	100-180						
Bk	180-280	1	5	12	6	9	6
C	280-330	1	15	17	8	8	4

Soil Profile Description for Pedon 91-6

Soil Classification: Typic Haplargid
Location: UTM691299
Parent Material: Basin floor alluvium
Physiography: La Mesa Basin floor

- A: 0-10; strong brown (7.5 YR 4/6) sandy loam; structureless; soft.
- Btk1: 10-40; strong brown (7.5 YR 5/6) sandy clay loam; structureless.
- Btk2: 40-70; reddish yellow (7.5 YR 6/6), and white (10 YR 8/2) nodules, sandy clay loam; moderate subangular blocky structure.
- Btk3: 70-85; reddish yellow (7.5 YR 6/6) sandy clay loam; strong subangular blocky structure.
- Bkm1: 85-100; pink (7.5 YR 8/3) sandy clay loam; moderate platy structure.
- Bkm2: 100-180; pinkish white (7.5 YR 8/2) sandy clay loam; moderate subangular blocky structure.
- Bk: 180-230; reddish yellow (7.5 YR 6/6), and white (7.5 YR 8/0) sandy clay loam; weak subangular blocky.
- 2Btk1: 230-250; reddish yellow (5 YR 6/6), and white (7.5 YR 8/0) sandy loam; moderate prismatic structure.
- 4Btk2: 250-270; yellowish red (5 YR 5/6), and white (7.5 YR 8/0) sandy loam; moderate subangular blocky structure.

Table A-45. Laboratory Data for Pedon 91-6 (La Mesa surface)

HORIZON	DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	> 2 mm VOLUME (%)	CARBONATE (%)	ORGANIC CARBON (%)
A	0-10	81	3	16	3	6	
Btk1	10-40	75	4	21	10	6	
Btk2	40-70	71	3	26	9	23	
Btk3	70-85	71	3	26	15	31	
Bkm1	85-100	76	2	22	34	64	
Bkm2	100-180	70	9	21	15	56	
Bk	180-230	72	8	20	23	59	
2Btk1	230-250	76	10	14	11	29	
2Btk2	250-270	68	15	17	9	38	

Table A-46. Sand Fractions for Pedon 91-6 (La Mesa surface)

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
A	0-10	3	15	21	10	23	11	83
Btk1	10-40	3	16	19	8	19	10	74
Btk2	40-70	6	11	13	7	20	11	69
Btk3	70-85	7	13	12	6	17	10	65
Bkm1	85-100	22	22	16	5	10	6	81
Bkm2	100-180	14	25	21	7	12	5	84

Table A-46, continued

HORIZON	DEPTH (cm)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TOTAL (%)
Bk	180-230	23	23	18	7	9	5	84
2Btk1	230-250	5	13	16	8	14	9	65
2Btk2	250-270	6	12	15	8	14	12	68

Table A-47. Highway 375 Loop (calcrete pedon)
Location: UTM799205

HORIZON	DEPTH (cm)	S (%)	Si (%)	C (%)	>2 mm by Weight	CaCO3 (%)	OC (%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE CLASS	COLOR	STRUCTURE	CONSISTENCY
C	0-24	82	4	14		1	0.4	0.1	3	16	15	42	16	sl	7.5 YR 5/6	cross-bedded	loose
Bk1	24-40	81	6	13	2	4	0.8	0.3	5	26	13	29	12	sl	7.5 YR 5/6	w. sbk	soft
Bk2	40-50	79	8	13	4	11	0.4	0.8	6	23	12	27	12	sl	7.5 YR 6/6	w. sbk	soft
Btk	50-65	75	9	16	18	14	0.6	1	4	20	10	23	12	sl	7.5 YR 7/4-8/2	w. sbk	slightly hard
Bkm_1	65-100	76	4	20		30	0.2	29	16	13	5	6	4	sl,scl	7.5 YR 8/2	platy	extremely hard
Bkm_2	100-150+	78	8	14		52	0.3	12	13	14	8	14	5	sl	7.5 YR 8/2	massive	extremely hard

Table A-48. Highway 375 Loop (pipe pedon)
Location: UTM799205

HORIZON	DEPTH (cm)	S (%)	Si (%)	C (%)	>2 mm by Weight	CaCO3 (%)	OC (%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE CLASS	COLOR	STRUCTURE	CONSISTENCY
C	0-12	85	3	12		0.6	0.2	1	13	28	11	27	13	ls	7.5 YR 6/6	cross-bedded	soft
A	12-20				4	0.5	0.1	0.4	5	24	14	33	13		7.5 YR 5/6	w. sbk	soft
Btk1	20-50	77	9	14	0.7	0.5	.03	2	5	22	14	29	15	sl	7.5 YR 5/6	m. sbk	slightly hard
Btk2	50-70	74	12	14	4	4	0.1	2	5	20	12	29	14	sl	7.5 YR 6/4	m. sbk.	slightly hard
Btk3	70-140+	75	11	14	4	2	0.1	1	4	20	13	30	13	sl	7.5 YR 5/8	w.sbk	v. friable

Table A-49. Trench 7b North
Location: UTM855295
Described: January 29, 1992

HORIZON	DEPTH (cm)	S (%)	Si (%)	C (%)	CaCO3 (%)	OC (%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE	MOIST COLOR	STRUCTURE	CONSISTENCY
C	0-25	80	3	17	0.6	.05	0.4	2	20	17	37	13	sl	5 YR 6/6	sl	soft
Ck	25-50	79	5	16	2	.03	0.6	4	25	16	30	12	sl	5 YR 6/6	sl	soft
2Btk1	50-60				4	.03	0.3	4	25	13	24	12		5 YR 5/6	w. sbk	slightly firm
2Btk2	60-80	78	2	20	7	0.8	1	4	19	10	30	12	sl	5 YR 5/6-6/4	m. sbk	slightly firm
2Btk3	80-100	82	4	14	4	0.2	0.8	5	20	18	26	12	sl	5 YR 6/6-7/3	w. sbk	slightly firm

Table A-50. Trench 7b Middle
Location: UTM855295
Described: January 29, 1992

HORIZON	DEPTH (cm)	S (%)	Si (%)	C (%)	Ca (%)	(%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE	MOIST COLOR	STRUCTURE	CONSISTENCY
C1	0-20	78	5	17	0.2	0.08	.09	3	22	17	35	13	sl	7.5 YR 6/6*	sl	soft
C2	20-40	73	5	22	0.3	0.23	0.2	4	26	15	30	11	scl	5 YR 4/4	sl	soft
C3	40-320	78	4	18	0.4	0.21	0.4	5	26	14	28	12	sl	5 YR 5/6	sl	soft

*dry color

Table A-51. Trench 7b South
Location: UTM855295
Described: January 29, 1992

HORIZON	DEPTH (cm)	S (%)	SI (%)	C (%)	CaCO3 (%)	OC (%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE	MOIST COLOR	STRUCTURE	CONSISTENCY
C	0-15	74	4	22	0.3	0.2	0.5	2	24	19	35	11	scl	7.5 YR 5/6	sl	soft
Ck	15-30	79	4	17	0.9	0.3	0.3	2	24	17	32	12	sl	7.5 YR 5/6	sl	soft
2Btk1	30-45	79	5	16	4	0.1	0.3	3	24	14	28	12	sl	5 YR 4/6	w. sbk	slightly firm
2Btk2	45-70	74	4	22	8	0.2	0.6	3	19	14	29	13	scl	5 YR 5/6-6/4	m. sbk	firm
2Btk3	70-90	80	4	16	5	.03	0.5	3	20	15	32	12	sl	5 YR 5/6-6/3	w. sbk	slightly firm

Table A-52. Trench 5
Location: UTM881302
Described: January 24, 1992

HORIZON	DEPTH (cm)	S (%)	SI (%)	C (%)	CaCO3 (%)	OC (%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE	MOIST COLOR	STRUCTURE	CONSISTENCY
C	0-10	84	2	14	0.3	0.3	.2	7	33	15	27	12	ls	7.5 YR 6/6	structure less	loose
A	10-20	80	2	18	0.5	0.3	0.6	6	24	13	31	14	sl	7.5 YR 4/4	structure less	soft
C'	20-65	84	1	15	0.6	0.1	0.7	6	23	14	31	13	sl	7.5 YR 5/6	structure less	soft
Ck	65-120	77	6	17	2	0.1	0.3	5	21	14	33	13	sl	7.5 YR 6/6	structure less	soft
Bkm	120-170	71	13	16	36	0.3	6	4	10	10	26	10	sl	7.5 YR 7/3	massive	soft

Table A-53. Booker Hill Gully Site
Location: UTM530580
Described December 6, 1991

HORIZON	DEPTH (cm)	S (%)	Si (%)	C (%)	>2 mm by Weight	CaCO3 (%)	OC (%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE CLASS	COLOR	STRUCTURE	CONSISTENCY
C	0-5	79	6	15	4	1	0.2	.3	1	10	18	42	16	sl	7.5 YR 5/6	granular	soft
Btk1	5-51	74	10	16		5	0.1	.6	2	9	16	36	15	sl	7.5 YR 5/6	m. sbk	s. hard
Btk2	51-65	78	10	12	15	4	0.3	2	4	12	16	34	14	sl	7.5 YR 5/6	m. sbk	s. hard
2Btk1	65-92	80	64	18		14	0.5	2	3	8	10	22	14	sl	7.5 YR 6/4	s. sbk	v. hard
2Btk2	92-120	65	9	26	32	29	0.1	0.8	2	8	9	18	11	scl	7.5 YR 5/6	s. sbk	ex. hard
3Btk1	120-170	74	11	15	34	28	0.6	2	4	11	10	19	10	sl	7.5 YR 6/6	s. sbk	ex. hard
3Btk2	170-205	75	8	17	31	29	0.3	2	4	11	9	18	10	sl	7.5 YR 7/4	s. sbk	ex. hard
3Bk	205-220+	70	10	20	54	37	0.7	6	4	10	9	19	9	sl,scl	7.5 YR 6/6	sl	

Table A-54. Old Coe Lake Site
Location: UTM667625
Described: December 12, 1991

HORIZON	DEPTH (cm)	S (%)	Si (%)	C (%)	>2 mm by Weight	CaCO3 (%)	OC (%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE CLASS	COLOR	STRUCTURE	CONSISTENCY
C1	0-20	55	23	22		9	2	0.5	2	16	10	14	16	scl	10 YR 5/3	platy	soft
C2	20-40	65	18	17		7	0.4	1	3	19	14	21	13	sl	10 YR 5/4	m. sbk	s. hard
E	40-47	63	20	17		8	0.3	0.6	3	17	11	17	15	sl	10 YR 5/4	m. sbk	s. hard
Btk	47-60	42	26	32	9	5	1	0.3	1	8	6	9	9	cl	10 YR 5/3	s. sbk	v. hard
Ck1	60-93	43	21	36	9	15	0.6	0.2	2	9	7	9	9	cl	10 YR 4/3	s. sbk	ex. hard
Ck2	93-113	57	14	29		3	0.3	0.3	3	16	11	15	10	scl	7.5 YR 5/4	s. sbk	hard

Table A-54, continued

HORIZON	DEPTH (cm)	S (%)	Si (%)	C (%)	>2 mm by Weight	CaCO3 (%)	OC (%)	VCS (%)	CS (%)	MS (%)	180 (%)	FS (%)	VFS (%)	TEXTURE CLASS	COLOR	STRUCTURE	CONSISTENCY
Ck3	113-130	42	26	32		16	0.8	0.2	2	6	6	9	9	cl	7.5 YR 5/4	s. sbk	v. hard
Ck4	130-148	30	38	32		12	0.4	0.1	0.9	4	3	6	11	cl	7.5 YR 6/4	s. sbk	v. hard
E'	148-156	64	16	20	4	11	0.1	.2	2	12	16	22	12	sl,scl	10 YR 6/4	m. sbk	s. hard
B'tk	156-203	74	12	14	5	14	0.1	2	10	23	12	18	14	sl	7.5 YR 5/6	s. sbk	hard
2Btk1	203-228	67	18	15	16	5	0.1	3	11	20	10	14	11	sl	7.5 YR 5/6	s. sbk	hard
2Btk2	228-253	65	12	23	9	5	0.5	2	10	21	11	15	10	scl	7.5 YR 4/6	s. sbk	v. hard
2Btk3	253-288	74	7	19	14	27	0.1	2	7	16	9	13	9	sl	7.5 YR 7/2	s. sbk	ex. hard
2Btk4	288-303+	73	9	18	21	21	.03	3	8	18	10	15	11	sl	7.5 YR 6/4	s. sbk	v. hard

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Appendix B

STATISTICAL ANALYSIS OF SOIL PROPERTIES

Mohammad H. Nash

Abstract

Areas of grassland and coppice dune lands cover the Fort Bliss Military Reservation. Numerical procedures were conducted to determine if grasslands or dune lands have unique properties that can explain their existence. Particle-size distribution and calcium carbonate content of soils were analyzed using a moving average, students' t-tests, and principal component analysis to determine points of inflection. Inflection points in dune lands were more influenced by sand fractions coarser than 0.25 mm, while grasslands showed inflection points influenced by <0.25 mm sand fractions. Principal component analysis grouped soils by their ratios of fine/very fine sand. The inflection points of soil carbonate did not coincide with sand fractions. The lack of agreement between sand fractions and soil carbonate content may be related to the nature of carbonate accumulation.

Introduction

Statistical criteria for separating coppice dune land from grassland based on soil properties was conducted as part of a geomorphology study of the Fort Bliss Military Reservation, southern New Mexico and western Texas. The aim was to understand soil changes resulting from desertification in the Holocene period, particularly in the last century.

Cluster and principal component analyses were applied to understand the distribution patterns of sand fractions, clay, and carbonates, and to find out which grain size was most abundant in various dune or grassland areas.

Methodology

For the purpose of this study the sampling sites were divided into 0-20 cm, and 20-40 cm depths.

Statistical Approach

Cluster analysis is an analytical technique that can be used to identify subgroups of individuals or objects. Specifically, the objective is to classify a sample of entities (individuasl or objects) into a small number of mutually exclusive groups, based on the properties of the entities. The groups are not predefined. Cluster analysis techniques measure some form of similarity or association of entities to determine how many groups may be identified in the samples. The cluster analysis of the sites was based on the results of a dendogram obtained from the distance matrix developed by the agglomerative method.

Principal component analysis is a multivariate method that finds a set of orthogonal axes in the direction of greatest variance among individuals. The components are ranked in order according to the proportion of the total variance for which they account. If the original variants are highly correlated, then a single principal component may express most of the variation and may be adequate as a measure of the individuals for many purposes. A statistical analysis system program (SAS/ETS 1982) was used to calculate the principal components and cluster analysis.

Table B-1. Results

SITE	LAND TYPE	UTM-X	UTM-Y
1	Dune	626	551
2	Dune	705	534
3	Dune	772	521
4	Dune	845	495
5	Grass	604	538
6	Grass	808	493
7	Grass	861	544
8	Grass	849	675
9	Grass	839	785
10	Grass	831	441
11	Grass	823	385
12	Dune	935	385
13	Dune	809	267

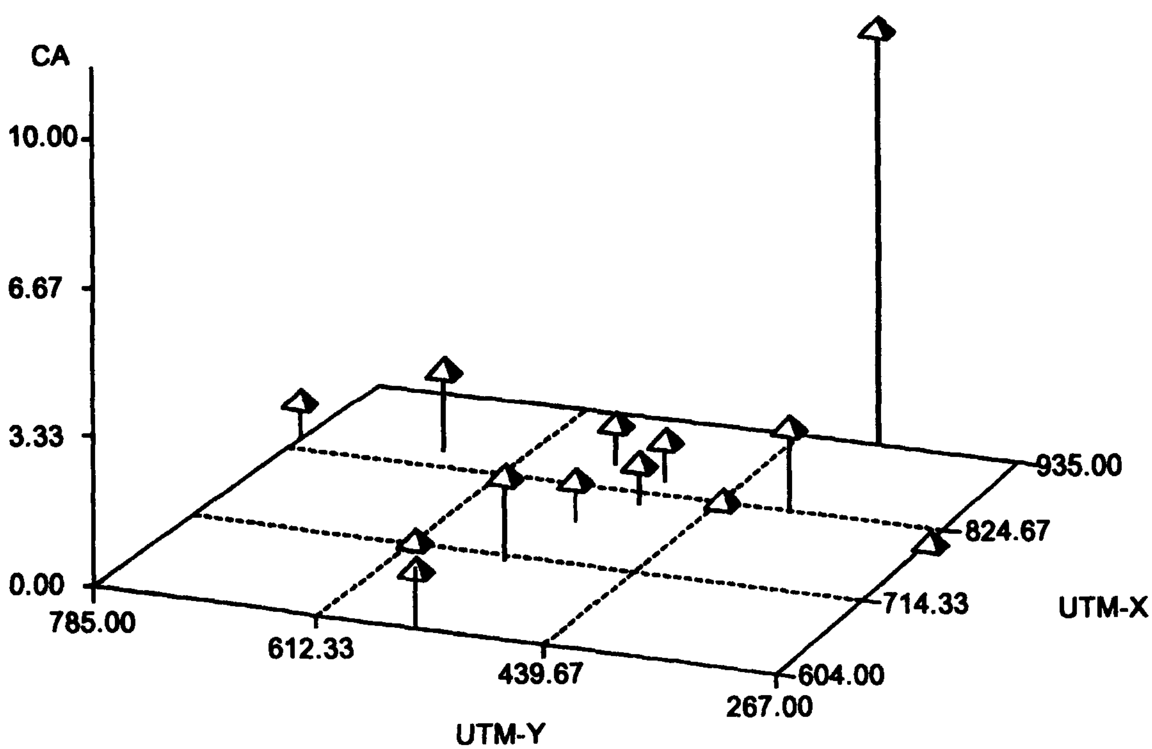

Figure B-1. Calcium Carbonate Content

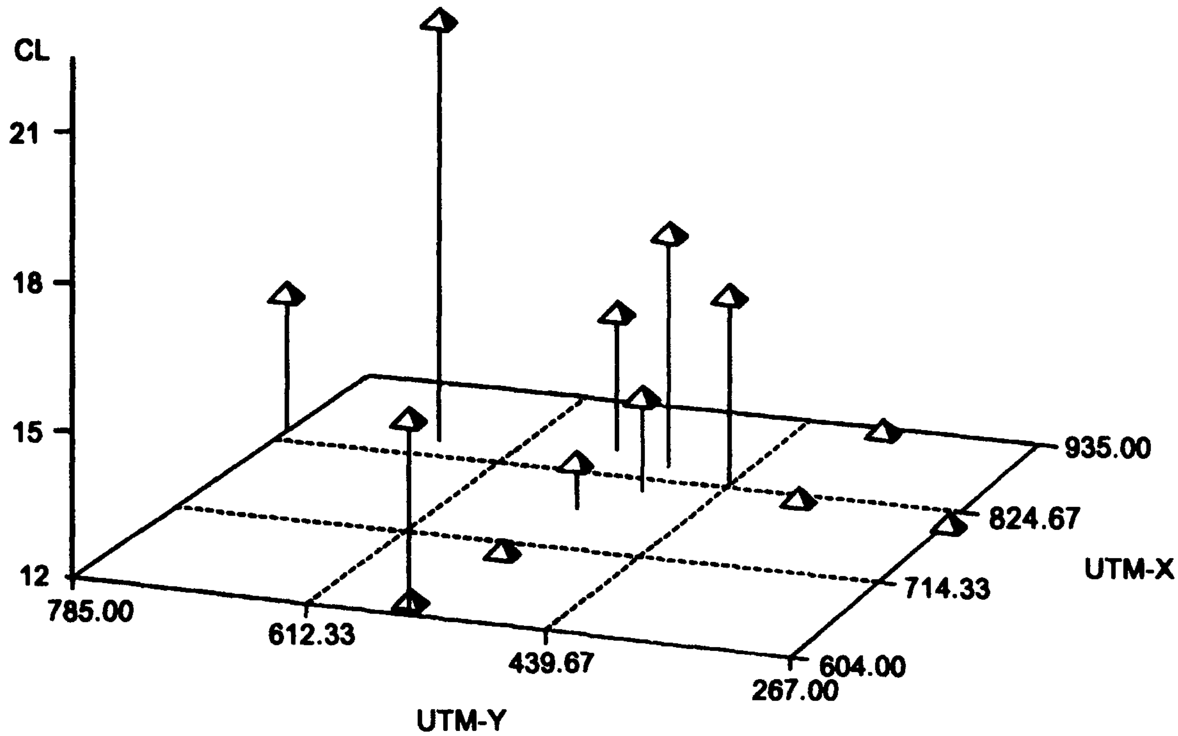

Figure B-2. Clay Content

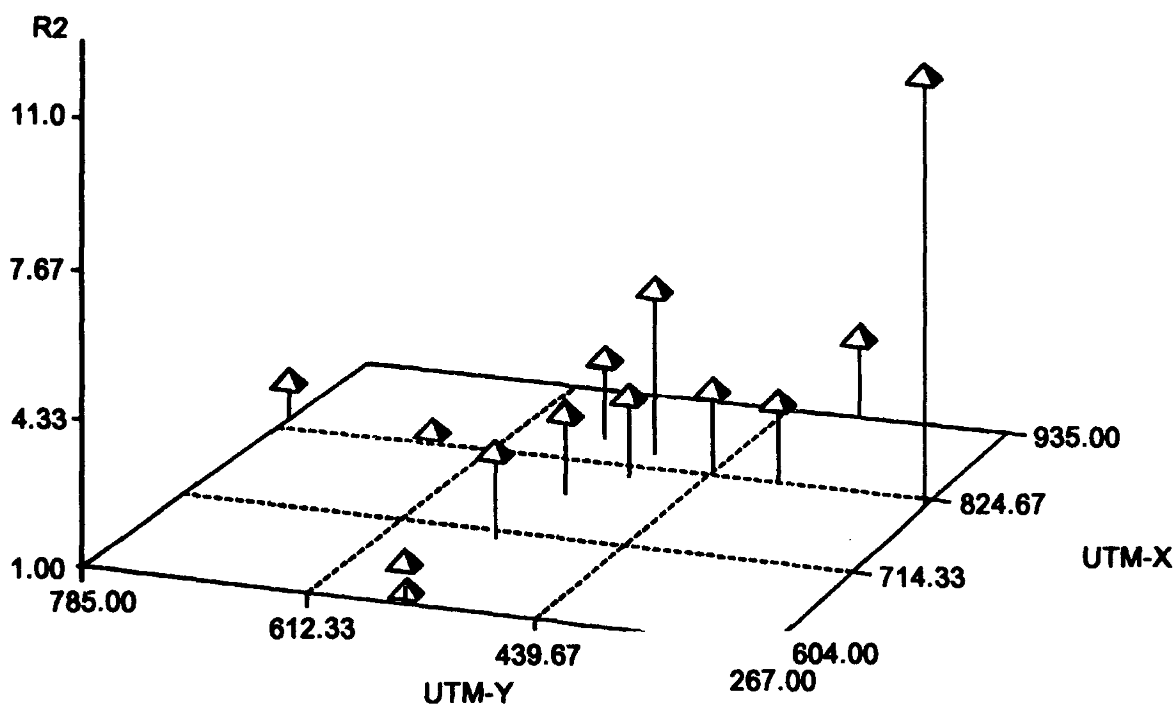

Figure B-3. Fine/Very Fine Sand

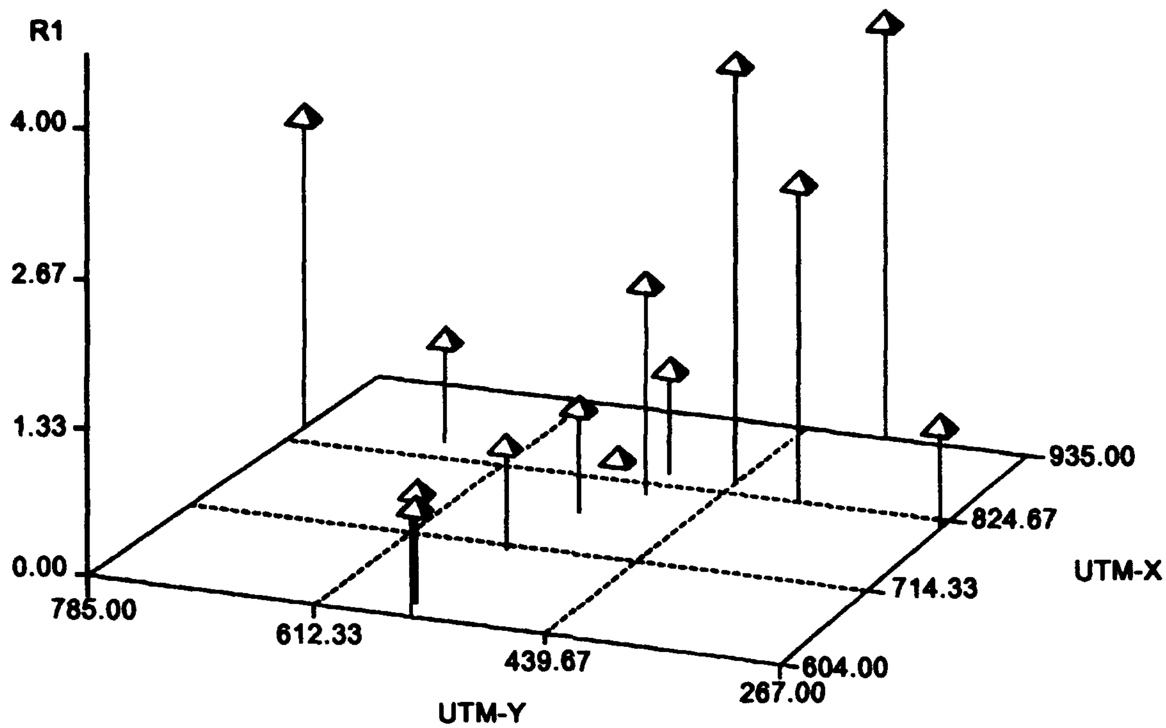

Figure B-4. Medium/Very Fine Sand

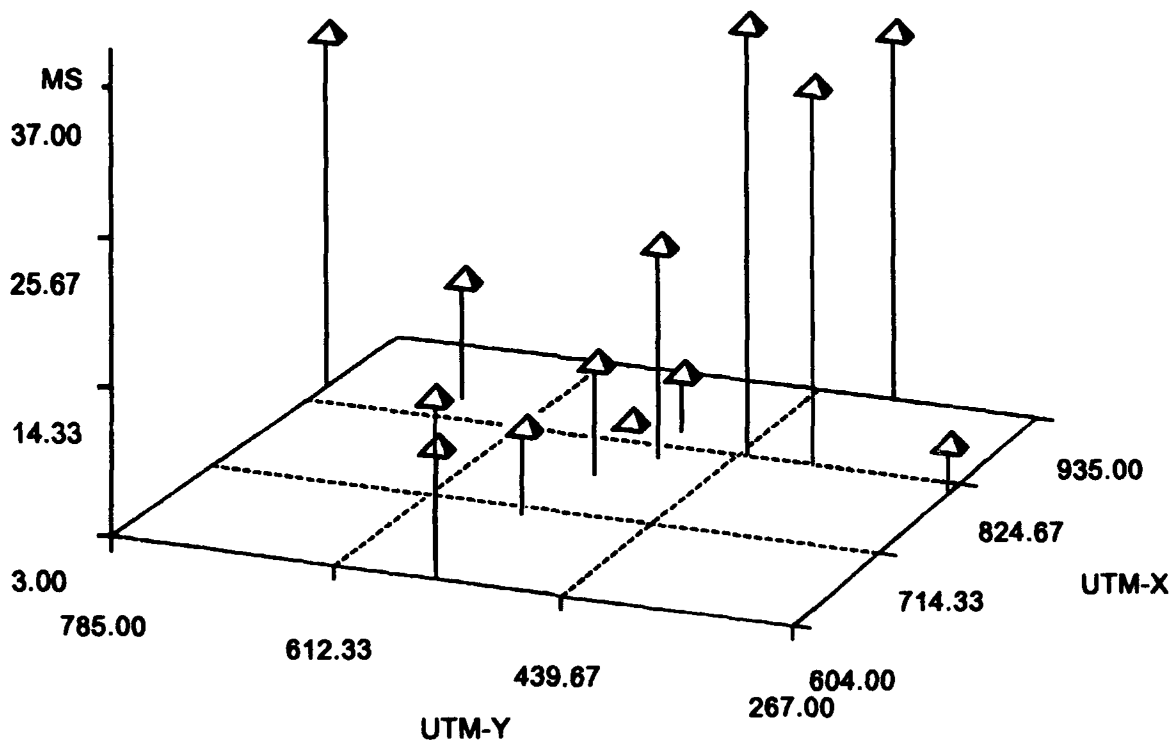

Figure B-5. Medium Sand

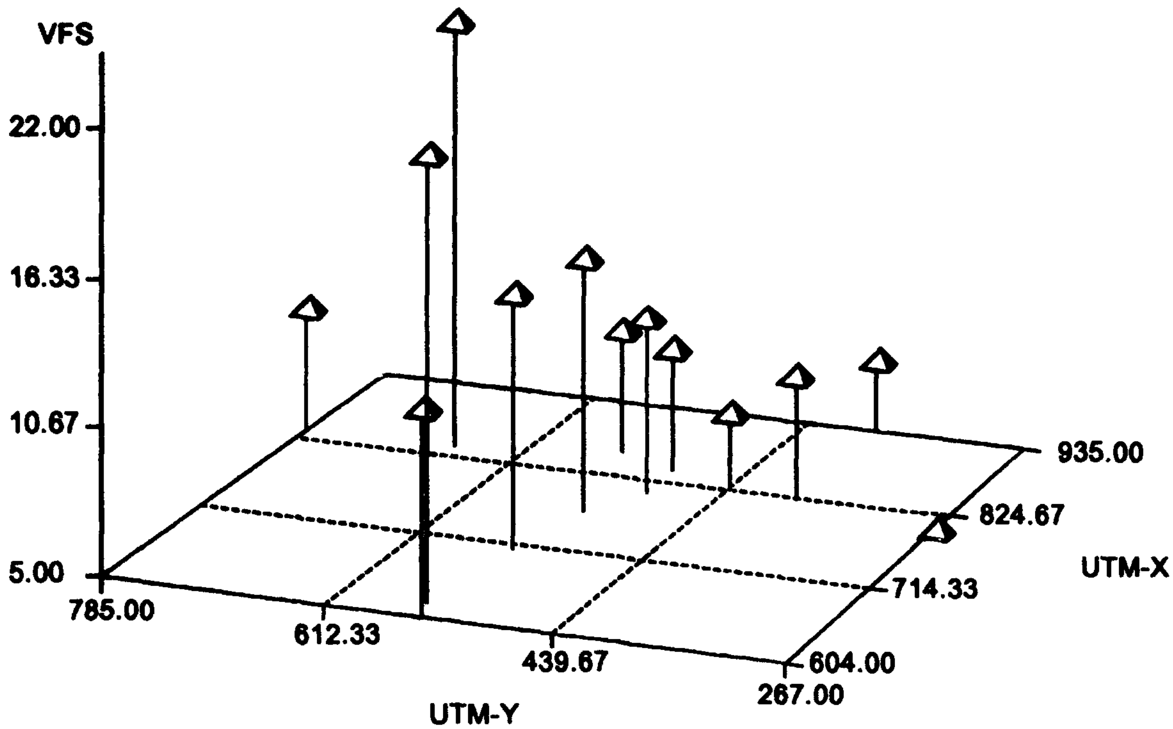

Figure B-6. Very Fine Sand

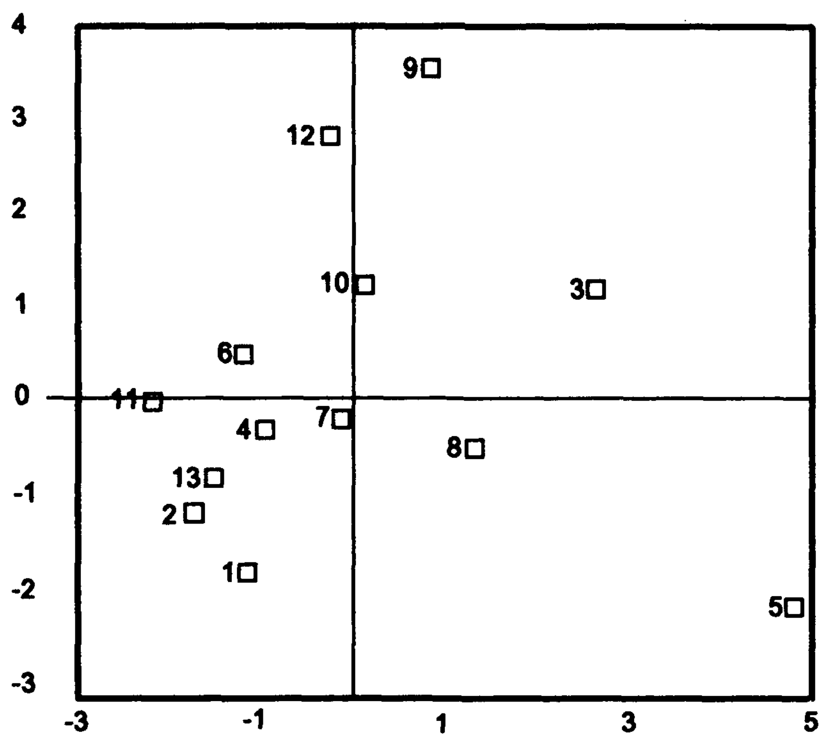

Figure B-7. Principal Component Analysis–First Layer

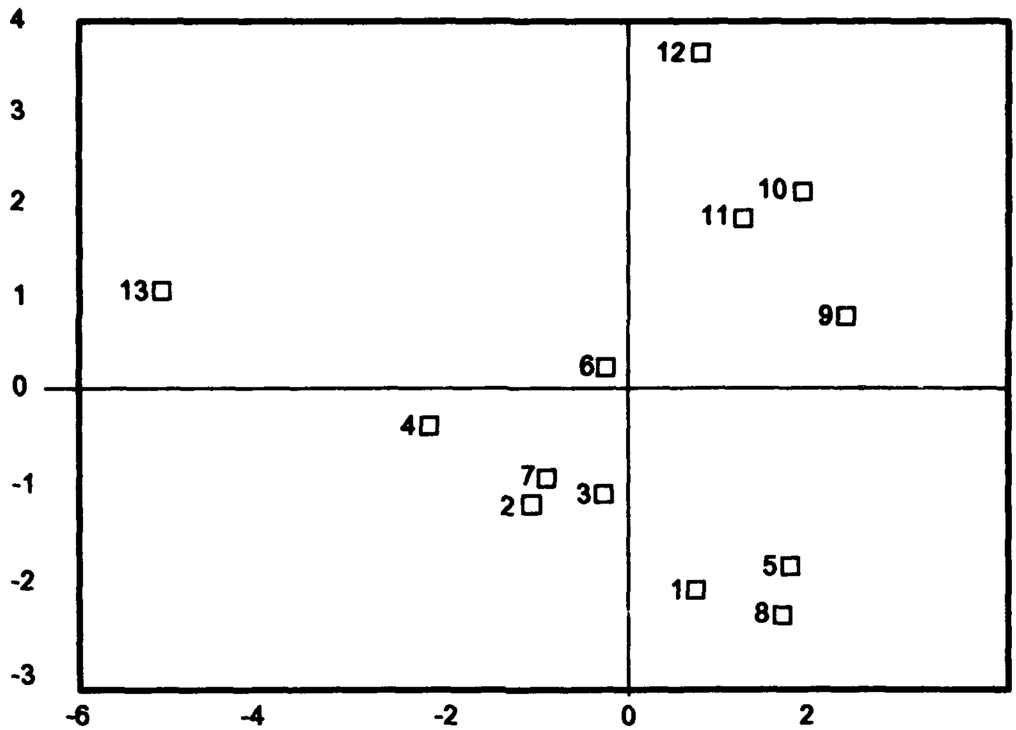

Figure B-8. Principal Component Analysis–Second Layer

Table B-4. Principal Component Analysis

FIRST LAYER				
	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
PRIH1	4.35535	1.22057	0.362946	0.36295
PRIH2	3.13478	1.58839	0.261232	0.62418
PRIH3	1.54639	0.39891	0.128866	0.75304
PRIH4	1.14748	0.30633	0.095623	0.84867
PRIH5	0.84115	0.31153	0.070096	0.91876
PRIH6	0.52961	0.29216	0.044135	0.9629
PRIH7	0.23745	0.12037	0.019788	0.98268
PRIH8	0.11708	0.04542	0.009757	0.99244
PRIH9	0.07167	0.0574	0.005972	0.99841
PRIH10	0.01426	0.01078	0.001189	0.9996
PRIH11	0.00348	0.00218	0.00029	0.99989
PRIH12	0.0013		0.000108	1
SECOND LAYER				
PRIH1	4.29122	1.54631	0.357602	0.3576
PRIH2	2.74492	1.1589	0.228743	0.58634

Table B-4, continued

SECOND LAYER, continued				
	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
PRIH3	1.58601	0.22099	0.132168	0.71851
PRIH4	1.36502	0.38797	0.113752	0.83226
PRIH5	0.97706	0.49429	0.081421	0.91369
PRIH6	0.48277	0.05665	0.040231	0.95392
PRIH7	0.42612	0.35946	0.03551	0.98945
PRIH8	0.06666	0.03627	0.005555	0.99498
PRIH9	0.03039	0.00574	0.002533	0.99751
PRIH10	0.02445	0.01966	0.002054	0.99957
PRIH11	0.00499	0.00479	0.000416	0.99998
PRIH12	0.0002		0.000016	1

Table B-5. Average Distance Between Clusters

SIMPLE STATISTICS

	X	Y	VCS	CS	MS	SHS	FS	VFS	CL	R1	R2	CA
MEAN	792.846	508.692	0.153846	2.84615	22.2308	19.5385	31.3077	9.76923	12.7692	2.38462	3.38462	2.46154
ST DEV	94.588	130.055	0.5547	1.62512	5.9882	4.3131	6.447	2.16617	1.4233	0.96077	1.04391	3.47887
CV			360.1	57.1	26.6	22.1	20.6	22.2	11.1	40.3	30.8	141.3
Skwness			3.61	1.53	0.86	0.65	0.18	1.30	1.3	0.39	0.1	1.42
Kurtosis			13.0	2.88	-0.40	-0.22	-1.09	1.40	1.05	-0.44	-0.99	0.58

CORRELATIONS

	X	Y	VCS	CS	MS	SHS	FS	VFS	CL	R1	R2	CA
X	1.0000	-0.1319	-0.5999	-0.3487	0.4853	-0.1575	0.0456	-0.3113	0.1198	0.5436	0.0800	0.0268
Y	-0.1319	1.000	0.0677	0.2462	0.0311	0.1597	-0.6421	0.1198	0.4520	-0.0663	-0.4128	0.0456
VCS	-0.5999	0.0677	1.0000	0.7680	-0.2625	-0.4555	-0.3872	0.3094	0.0487	-0.4330	-0.3985	0.4783
CS	-0.3487	0.2462	0.7680	1.0000	0.2095	-0.5222	-0.5439	0.1785	0.3076	0.0411	-0.3552	0.1463
HS	0.4856	0.0311	-0.2625	0.2095	1.0000	-0.2149	-0.4337	-0.1562	0.3197	0.8668	-0.1887	0.0545
SHS	-0.1575	0.1597	-0.4555	-0.5222	-0.2149	1.0000	0.4161	-0.4762	-0.1138	0.0665	0.5980	-0.3956
FS	0.0456	-0.6421	-0.3872	-0.5439	-0.4337	0.4161	1.0000	-0.4241	-0.5093	-0.0880	-0.8477	-0.4936
VFS	-0.3113	0.1198	0.3094	0.1785	-0.1562	-0.4762	-0.4241	1.0000	0.4408	-0.5945	-0.7314	0.2365
CL	0.1198	0.452	0.0487	0.3076	0.3197	-0.1138	-0.5093	0.4408	1.0000	0.0094	-0.3840	-0.0440
R1	0.5436	-0.0663	-0.4330	0.0411	0.8668	0.0665	-0.0880	-0.5945	0.0094	1.0000	0.2557	-0.1323
R2	0.0800	-0.4128	0.3985	-0.3552	-0.1887	0.5980	0.8477	-0.7314	-0.3840	0.2557	1.0000	-0.5807
CA	0.0268	0.0456	0.4783	0.1463	0.0545	-0.3956	-0.4936	0.2365	-0.0440	-0.1323	-0.5807	1.0000

Summary and Conclusions

Distribution of sand grains showed that dune land has less very fine sand than does grassland. This may be related to wind intensity and velocity. Coarse grains are carried by the wind a shorter distance than fine grains. The result of this limiting competency is reflected at the coarse-grained end of the frequency distribution curve by the lack of a "tail" usually present in a normal curve, resulting in positive skewness. Coarser grains (greater than 0.25 mm) showed positive correlation with the UTM-Y axis (northward direction). The finer grain (less than 0.25 mm) showed positive correlation with the UTM-X axis (eastward direction). This coincides with the prevailing wind direction in this area, which is from the southwest.

Dendograms clustered soil sites into two groups at cluster level 0.4. These two groups correspond with the distribution of dune and grasslands.

A plot of the first component for each of the sampling sites produced a scatter diagram. The positions of the sites in multidimensional character space have been projected onto the plane of the first and second principal components, so the scatter diagram can be the most informative display of site distribution. The scatter diagrams suggest each site has its own identity or property. That is, properties are dissimilar enough that sites cannot be grouped together. However, sites 1, 2, 3, and 4 of the dune land are more similar to each other. The analytical results were compared to aerial photographs that validated the ground research in these study environments.

REFERENCES

Amundson, R.G., O.A. Chadwick, J.M. Sowers, and H.E. Doner
1989 The Stable Isotope Chemistry of Pedogenic Carbonates at Kyle Canyon, Nevada. *Soil Science Society of American Journal* 53:210.

Antevs, Ernst
1955 Geologic-climatic Dating in the West. *American Antiquity* 20:317-335.

Bartolome, James W., Klukkert, Steven E., and Barry, W. James
1986 Opal Phytoliths as Evidence for Displacement of Native Californian Grassland. *Madrono* 33:217-222.

Bates, R.L., and J.A. Jackson
1987 *Glossary of Geology*. Third edition, American Geological Institute, Alexandria, Virginia.

Benedict, J.B.
1979 Getting Away From it All–A Study of Man, Mountains, and the Two-drought Altithermal. *Southwestern Lore* 45(3):1-12.

Bigham, J.M., W.F. Jaynes, and B.L. Allen
1980 Pedogenic Degradation of Sepiolite and Palygorskite on the Texas High Plains. *Soil Science Society of America Journal* 44:159-167.

Blair, T.C., J.S. Clark, and S.G. Wells
1990 Quaternary Continental Stratigraphy, Landscape Evolution, and Application to Archeology: Jarilla Piedmont and Tularosa Graben Floor, White Sands Missile Range, New Mexico. *Geological Society of America Bulletin* 102:749-759.

Boggs, S., Jr.
1987 *Principles of Sedimentology and Stratigraphy*. Merill Publishing Company, Columbus, Ohio.

Brown, D.A.
1984 Prospects and Limits of Phytolith Key for Grasses in the Central United States. *Journal of Archaeological Science* 11:345-368.

Brown, David E.
1982a Plains and Great Basin Grassland. In Biotic Communities of the American Southwest–United States and Mexico, edited by David E. Brown. *Desert Plants* 4(1-4):115-121.

1982b Semidesert Grassland. In Biotic Communities of the American Southwest–United States and Mexico, edited by David E. Brown. *Desert Plants* 4(1-4):123-131.

1982c — Chihuahuan Desert Scrub. In Biotic Communities of the American Southwest–United States and Mexico, edited by David E. Brown. *Desert Plants* 4(1-4):169-179.

Bull, W.B.
1991 — *Geomorphic Responses to Climatic Change.* Oxford University Press, New York.

Buol, S.W., F.D. Hole, and R.J. McCracken
1989 — *Soil Genesis and Classification.* Third Edition, Iowa State University Press, Ames.

Carmichael, D.L.
1986 — Archaeological Survey in the Southern Tularosa Basin of New Mexico. *Historic and Natural Resources Report* No. 3. Directorate of Environment, Fort Bliss, Texas.

Campbell, J.
1987 — *Introduction to Remote Sensing.* Guilford Press, New York.

Cerling, T.E.
1984 — The Stable Isotopic Composition of Modern Soil Carbonate and its Relationship to Climate. *Earth and Planetary Science Letters* 71:229-240.

Cerling, T.E., J. Quade, Y.Wang, and J.R. Bowman
1989 — Carbon Isotopes in Soils and Paleosols as Ecology and Paleoecology Indicators. *Nature* 341:138-139.

Chadwick, O.A., and Davis, J.O.
1990 — Soil-forming Intervals Caused by Eolian Sediment Pulses in the Lahontan Basin, Northwestern Nevada. *Geology* 18:243-246.

Crompton, E.
1967 — Soil Formation. In Selected Papers in Soil Formation and Classification, edited by J.V. Drew. *Soil Science Society of America Special Publication,* Madison, Wisconsin.

Daniels, R.B., and R.D. Hammer
1992 — *Soil Geomorphology.* John Wiley & Sons, Inc., New York.

Dansgaard, W.
1964 — Stable Isotopes in Precipitation. *Tellus* 16(4):436-468.

Davis, J.O., and F. Nials
1988 — Geomorphology of the Study Area. In *Archaeological Resources of the Santa Teresa Study Area, South-Central New Mexico,* edited by J.C. Ravesloot. BLM-NM-GI-88-023-3120, Cultural Resource Management Division, Arizona State Museum, University of Arizona, Tucson.

Dick-Peddie, W.A.
1975 — Vegetation of Southern New Mexico. In *Guidebook of the Las Cruces Country,*

edited by W.R. Seager et al., pp. 81-84. New Mexico Geological Society 26th Field Conference, New Mexico Geologic Society, Socorro.

Dohrenwend, J.C.
1987 Basin and Range. In *Geomorphic Systems of North America,* edited by W.L. Graf, Geological Society of North America, Inc., Boulder, Colorado.

Dohrenwend, J.C., W.B. Bull, L.D. McFadden, R.S.U. Smith, and S.G. Wells
1991 Quaternary Geology of the Basin and Range Province in California. In Quaternary Non-glacial Geology; Conterminous U.S., edited by R.B. Morrison, *The Geology of North America,* K-2, Geological Society of America, Boulder, Colorado.

Evans, L.J.
1978 Quantification and Pedological Processes in Quaternary Soils. In *Geo Abstracts,* edited by W.C. Mahaney. University of East Anglia, England.

Galloway, R. W.
1983 Full-glacial Southwestern United States: Mild and Wet or Cold and Dry. *Quaternary Research* 19:236-248.

Gee, G.W., and J.W. Bauder
1986 Particle-size Analysis. In Methods of Soil Analysis, Part 1, Second Edition, edited by A. Klute, pp. 383-411. *Agron. Monograph* 9, ASA and SSSA, Madison, Wisconsin.

Gile, L.H.
1990 Chronology of Lava and Associated Soils Near San Miguel, New Mexico. *Quaternary Research* 33:37-50.

1987a Late Holocene Displacement Along the Organ Mountains Fault in Southern New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Circular* 196, p. 43.

1987b A Pedogenic Chronology for Kilbourne Hole, Southern New Mexico: II, Time of the Explosion and Soil Events Before the Explosions. *Soil Science Society of America Journal* 51:752-760.

1977 Holocene Soils and Soil Geomorphic Relations in a Semi-arid Region of Southern New Mexico. *Quaternary Research* 7:112-132.

1975 Holocene Soils and Soil Geomorphic Relations in a Semi-arid Region of Southern New Mexico. *Quaternary Research* 5:321-360.

1966 Coppice Dunes and the Rotura Soil. *Soil Science Society of America Proceedings* 30:657-660.

Gile, L.H., and J.W. Hawley
1972 The Prediction of Soil Occurrence in Certain Desert Regions of the Southwestern United States. *Soil Science Society of America Journal* 36:119-124.

1968 Age and Comparative Development of Desert Soils at the Gardner Springs Radiocarbon Site, New Mexico. *Soil Science Society of America Proceedings* 32:709-716.

Gile, L.H., and R.B. Grossman
1979 The Desert Project Soil Monograph. *National Technical Information Service,* PB80-135304, Springfield, Virginia.

Gile, L.H., F.F. Peterson, and R.B. Grossman
1966 Morphological and Genetic Sequences of Carbonate Accumulation in Desert Soils. *Soil Science* 101:347-360.

Gile, L.H., J.W. Hawley, and R.B. Grossman
1981 Soils and Geomorphology in the Basin and Range Area of Southern New Mexico–Guidebook to the Desert Project. *New Mexico Bureau of Mines and Mineral Resources Memoir* 39, Socorro.

Gish, Jannifer W.
1989 Pollen Analysis of the Tator Hills Sites. Ms. in possession of the author.

Gould, F.N., and R.B. Shaw
1983 *Grass Systematics.* Texas A&M University Press, College Station.

Hall, G.F.
1983 Pedology and Geomorphology in Pedogenesis and Soil Taxonomy, Part 1. In *Concepts and Interactions,* edited by L.P. Wilding et al., p. 303. Elsevier, Amsterdam.

Harbour, R.L.
1972 Geology of the Northern Franklin Mountains. *U.S. Geological Survey, Bulletin* 1298, p. 129.

Hardie, C.H.
1958 The Pennsylvanian Rocks of the Northern Hueco Mountains. *Guidebook to Hueco Mountains,* pp. 43-45. West Texas Geological Society.

Harris, Arthur H.
1987 Reconstruction of Mid-Wisconsin Environments in Southern New Mexico. *National Geographic Research* 3(2):142-151.

Hawley, J.W.
1992 *Geomorphic Setting and Late Quaternary History of Pluvial Lake Basins in the Southern New Mexico Region.* Paper presented at the Conference on the Paleoecology of Pendejo Cave and its Environments, April 3-6, 1992, Orogrande, New Mexico.

1975 Quaternary History of Doña Ana County Region, South-central New Mexico. In

Guidebook of the Las Cruces Country, edited by W.R. Seager et al., pp. 139-150. New Mexico Geological Society 26th Field Conference, New Mexico Geological Society, Socorro.

1965 Geomorphic Surfaces Along the Rio Grande Valley from El Paso, Texas, to Caballo Reservoir, New Mexico. *Guidebook 16th Field Conference,* pp. 188-198. New Mexico Geological Society.

Hawley, J.W., F.E. Kottslowski, W.R. Seager, W.E. King, W.S. Strain, and D.V. LeMone
1969 The Santa Fe Group in the South-central New Mexico Border Region, edited by F.E. Kottslowski and D.V. LeMone. Border Stratigraphy Symposium, *New Mexico Bureau of Mines and Mineral Resources Circular* 104, Socorro.

Hawley, J.W., G.O. Bachman, and K. Manley
1976 Quaternary Stratigraphy in the Basin and Range and Great Plains Provinces, New Mexico and Western Texas. In *Quaternary Stratigraphy of North America,* edited by W.D. Mahaney, pp. 235-274. Cowden, Hutchinson, and Ross, Inc., Stroudsburg, Pennsylvania.

Hays, P.D., and E.I. Grossman
1991 Oxygen Isotopes in Meteoric Calcite Cements as Indicators of Continental Paleoclimate. *Geology* 19:441-444.

Isphording, W.C.
1973 Discussion of the Occurrence and Origin of Sedimentary Palygorskite-sepiolite Deposits. *Clays Clay Miner* 21:391-401.

Izett, G.A., and R.E. Wilcox
1982 Map showing localities and inferred distributions of the Huckleberry Ridge, Mesa Falls, and Lava Creek ash beds (Pearlette family ash beds) of Pliocene and Pleistocene age in the western United States and southern Canada. *U.S. Geological Survey Miscellaneous Investigations Series, Map* 1-1325, Denver, Colorado.

Jackson, M.L.
1973 *Soil Chemical Analysis–Advanced Course.* M.L. Jackson, Madison, Wisconsin.

Kearney, Thomas H., and Robert H. Peebles
1960 *Arizona Flora.* University of California Press, Berkeley.

Kelly, E.F., R.G. Amundson, B.D. Marion, and M.J. DeNiro
1991 Stable Carbon Isotopic Composition of Carbonate in Holocene Grassland Soils. *Soil Science Society of America Journal* 55:1651-1658.

Kelly, S.A., and J.P. Matheny
1983 Geology of the Anthony Quadrangle, Doña Ana County, New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Geologic Map* 54, scale 1:24,000.

Kipp, J.
1992 *Lithologic Discrimination Using Side-looking Airborne Radar in the Organ Mountains, New Mexico.* Unpublished master's thesis, New Mexico State University.

Kunze, G.W., and J.B. Dixon
1986 Pretreatment for Mineralogical Analysis. In Methods of Soil Analysis, Part 1, Second Edition. *Agron. Monograph* 9, ASA and SSSA, Madison, Wisconsin.

Lehr, J. Harry
1978 *A Catalogue of the Flora of Arizona.* Desert Botanical Garden, Phoenix, Arizona.

Long, M.
1975 *Radar Reflectivity of Land and Sea.* Lexington Books, Lexington, Massachusetts.

Lowe, J.J., and M.J.C. Walker
1987 *Reconstructing Quaternary Environments.* Longman, England.

Machette, M.N.
1985 Calcic Soils of the Southwestern United States. In Soils and Quaternary Geology of the Southwestern United States, edited by D.L. Weide, pp. 1-21. *Geological Society of America Special Paper* 203. Boulder, Colorado.

Mack, G.H., D.R. Cole, T.H. Giordano, W.C. Schaal, and J.H. Barcelos
1991 Paleoclimatic Controls on Stable Oxygen and Carbon Isotopes in Caliche of the Abo Formation (Permian), South-central New Mexico, USA. *Journal of Sedimentary Petrology* 61:458-472.

Malm, N.R., and F.E. Houghton
1977 Climatic Guide, Las Cruces, 1851-1976. *New Mexico State University Agricultural Experiment Station Research Report* 350, Las Cruces.

Mayer, L., Gerson, R., and Bull, W.B.
1984 Alluvial Gravel Production and Deposition: Useful Indicator of Quaternary Climatic Changes in Deserts. In Channel Processes; Water, Sediment, Catchment Controls, edited by A.P. Schick, pp. 137-151. *Catena Supplement* 5, p. 137-151.

Mellett, J.
1990 Ground-penetrating Radar Enhances Knowledge of Earth's Surface Layer. *Geotimes,* September 12-14.

Medellin-Leal, F.
1982 The Chihuahuan Desert. In *Reference Handbook on the Deserts of North America,* edited by G.L. Bender. Greenwood Press, Connecticut.

Monger, H.C., L.A. Daugherty, and L.H. Gile
1991 A Microscopic Examination of Pedogenic Calcite in an Aridisol of Southern New Mexico. p. 37-60. In Occurrence, Characteristics, and Genesis of Carbonate,

Gypsum, and Silica Accumulations in Soils, edited by W.D. Nettleton. *Soil Science Society of America Special Publication* No. 26. Soil Science Society of America, Madison, Wisconsin.

Morrison, R.B.
1991 Quaternary Geology of the Southern Basin and Range Province. In Quaternary Non-glacial Geology: Conterminous U.S., edited by R.B. Morrison, pp. 353-371. *The Geology of North America,* v. K-2, p. 353-371. Geological Society of America, Boulder, Colorado,

Neal, J.T., R.E. Smith, and B.F. Jones
1983 Pleistocene Lake Trinity, An Evaporite Basin in The Northern Jornada Del Muerto, New Mexico. In *New Mexico Geological Society Guidebook,* 34th Field Conference, Soccoro Region II.

Nelson, D.W. and L.E. Sommers
1982 Total Carbon, Organic Carbon, and Organic Matter. In Methods of Soil Analysis, Part 2, 2nd Edition, edited by A. Page. *Agronomy* 9:539-579.

Noyes, P.T. and M.F. Schmader
1988 Environmental Overview. In *The Border Star 85 Survey,* edited by Seaman, T.J. W.H. Doleman, and R.C. Chapman. University of New Mexico.

Ollendorf, Amy L., Mulholland, Susan C., and Rapp, George Jr.
1988 Phytolith Analysis as a Means of Plant Identification: Arundo Donax and Phragmites Communis. *Annals of Botany,* Vol. 61, p. 209-214.

Parry, W.T. and Reeves, C.C., Jr.
1968 Sepiolite from Pluvial Mound Lake, Lynn and Terry Counties, Texas. *The American Mineralogist* 53:984-993.

Pease, Douglas S.
1967 Opal Phytoliths as Indicators of Paleosols. Master's thesis, New Mexico State University.

Peterson, F.F.
1981 Landforms of the Basin and Range Province, Defined for Soil Survey. *Nevada Agricultural Experiment Station, Technical Bulletin* 28, 52 p.

Peterson, F.F., W.E. Dollarhide, and G.S. Staidle.
Intermontane-basin Landforms in the Basin and Range Province. In *Proceedings of the Fourth International Soil Correlation Meeting (ISCOM): Characteristics, Classification and Utilization of Aridisols*, edited by J.M. Kimble et al. USDA, Washington, D.C.

Pigott, J.D.
1977 Reconnaissance Geology: Implications for Analysis of Human Occupation. Part III:

Botanical and Geological Studies. In A Cultural Resource Inventory and Assessment of McGregor Guided Missile Range, Otero County, New Mexico. *Texas Archeological Survey Research Report* No. 65. University of Texas at Austin.

Piperno, D.R.
1988 *Phytolith Analysis: An Archaeological and Geological Perspective.* Academic Press, San Diego.

Quade, J., Cerling, T.E., and Bowman, J.R.
1989 Systematic Variations in Carbon and Oxygen Isotopic Composition of Pedogenic Carbonate Along Elevation Transects in the Southern Great Basin, United States. *Geological Society of American Bulletin* 101:464-475.

Reeves, C.C.
1973 The Full-glacial Climate of the Southern High Plains, West Texas. *Journal of Geology* 81:693-704.

Rhoades, J.D.
1982 Soluble Salts. In Methods of Soil Analysis. Part 2. Second Edition, edited by A.L. Page et al. *Agronomy* 9:167-178.

Ritter, D.F.
1986 *Process Geomorphology.* Second Edition. WCB Publishers.

Richards, L.A.
1954 Diagnosis and Improvement of Saline Alkaline Soils. U.S. Salinity Lab. *USDA Handbook* 60. U.S. Government Printing Office, Washington, D.C.

Rovner, Irwin
1971 Potential of Opal Phytoliths for Use in Paleoecological Reconstruction, *Quaternary Research,* Vol. 1, pp. 343-359.

Ruhe, R.V.
1975 *Geomorphology, Geomorphic Processes, and Surficial Geology.* Boston Houghton Mifflin Company.

1969 Principles of Dating Pedogenic Events in the Quaternary. *Soil Science* 107:398-401.

1967 Geomorphic Surfaces and Surficial Deposits in Southern New Mexico. *New Mexico Bureau of Mines and Mineral Resources Memoir* 18. Socorro.

Salomons, W., and W.G. Mook
1986 Isotope Geochemistry of Carbonates in the Weathering Zone. In *Handbook of Environmental Isotope Geochemistry,* Vol. 2, edited by P. Fritz and J. Fontes, pp. 239-269. Elsevier, Amsterdam, The Netherlands.

Schmidt, P.G., and Craddock, C.

1964 The Geology of the Jarilla Mountains, Otero County, New Mexico. *New Mexico Bureau of Mines and Mineral Resources Bulletin* 82, p. 55.

Schlesinger, W.H.

1985 The Formation of Caliche in Soils of the Mojave Desert, California. *Geochimica et Cosmochemica Acta* 49:57-66.

Seager, W.R.

1981 Geology of Organ Mountains and Southern San Andres Mountains, *New Mexico. New Mexico Bureau of Mines and Mineral Resources Memoir* 36, p. 97.

1980 Quaternary Fault System in the Tularosa and Hueco Basin, Southern New Mexico and West Texas. In *New Mexico Geological Society 31st Annual Field Conference*, pp. 131-135.

Seager, W.R., R.E. Clemons, and J.W. Hawley

1975 Geology of Sierra Alta Quadrangle, Doña Ana County, New Mexico. *New Mexico Bureau of Mines and Mineral Resources Bulletin* 102, p. 56 .

Seager, W.R., Hawley, J.W., Kottlowski, F.E., and Kelley, R.E.

1987 Geologic map of east half of Las Cruces and northeast of El Paso, 1x2 sheets. *New Mexico Bureau of Mines and Mineral Resources Geological Map* 57, scale: 1:125,000, 3 sheets.

Siegal, B. and Gillespie, A., eds.

1980 *Remote Sensing in Geology.* John Wiley and Sons, New York.

Singer, A.

1989 Palygorskite and Sepiolite Group Minerals. In Minerals in Soil Environments. Second Edition. *Soil Science Society of America Book Series* No. 1.

Smith, G.I, and Street-Perrott, F.A.

1983 Pluvial Lakes of the Western United States. In The Late Pleistocene, edited by Stephen C. Forter, pp. 259-293. *Late-Quaternary Environments of the United States,* Volume 1, edited by H. E. Wright, Jr. University of Minnesota Press, Minneapolis.

Smith, H., and Wilding, L.P.

1972 Genesis of Argillic Horizons in Ochraqualfs Derived from Fine Textured Till Deposits of Northwestern Ohio and Southeastern Michigan. *Soil Science Society of America Proceedings* 36:808-815.

Soil Survey Staff

1992 Keys to Soil Taxonomy. *SMSS Technical Monograph* No. 19. 5th (ed.). Pocahontas Press, Inc. Blacksburg, Virginia.

1982 Procedures for Collecting Soil Samples and Methods of Analysis for Soil Survey.

Soil Survey Investigations Report No. 1. USDA-Soil Conservation Service, Washington, D.C.

1981 *Soil Survey Manual.* Chapter 4. 430-V-SSM. USDA-Soil Conservation Service. Washington, D.C.

1975 *Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Survey.* U.S. Government Printing Office, Washington, D.C.

Spaulding, W. Geoffrey, Estella B. Leopold, and Thomas R. Van Devender
1983 Late Wisconsin Paleoecology of the American Southwest. In The Late Pleistocene, edited by Stephen C. Porter, pp. 259-293. *Late-Quaternary Environments of the United States,* Volume 1, edited by H. E. Wright, Jr. University of Minnesota Press, Minneapolis.

Strain, W.S.
1966 Blancan Mammalian Fauna and Pleistocene Formations, Hudspeth County, Texas. *Texas Memorial Museum Bulletin* 10, p. 55. University of Texas, Austin.

Stratton, G.R.
1982 *Pedogenic Study of a Soil-geomorphic Surface Age Sequence.* Master's thesis, New Mexico State University, Las Cruces.

Teng, W.
1985 An Analysis of SIR-A Imagery for Mapping Soils in the Las Cruces Area of New Mexico. Technical paper from the *51st Annual Meeting of the American Society of Photogrammetry* 1:341-351.

Twiss, Page C.
1987 Grass-Opal Phytoliths as Climatic Indicators of the Great Plains Pleistocene. In Quarternary Environments of Kansas, edited by W.C. Johnson. *Kansas Geological Survey Guidebook Series* 5:179-188.

U.S. Department of Agriculture (USDA)
1981 *Soil Survey of Otero Area, New Mexico.* Soil Conservation Service and National Forest Service, Santa Fe.

Van Devender, T.R.
1990 Late Quaternary Vegetation and Climate of the Chihuahuan Desert, United States and Mexico. In *Packrat Middens: The Last 40,000 Years of Biotic Change.* Edited by J.L. Betancourt et al., pp. 104-133. University of Arizona Press, Tucson.

Von Finger, K., and A. Horowitz
n.d. Pollen Analysis of Buried Paleosols from the Tularosa Basin, New Mexico. Ms. on file, Directorate of Environment, Fort Bliss, Texas.

Walkely, A., and I.A. Black
1934 An Examination of the Degtjareff Method for Determining Soil Organic Matter and a

Proposed Modification of the Chromic Acid Titration Method. *Soil Science* 37:29-38.

Williams, G.E., and H.A. Polach
1971 Radiocarbon Dating of Arid-zone Calcareous Paleosols. *Geological Society of America Bulletin* 82:3069-3086.

Young, J., R. Caldecott, and L. Peters, Jr.
1988 Underground Radar Research at Ohio State University. In *Radar Applications,* edited by M. Skolnik. IEEE Press, New York.

Yurtsever, Y. and J.R. Gat.
1981 Atmospheric Waters. p. 103-142. In Stable Isotope Hydrology-Deuterium and Oxygen-18 in the Water Cycle, edited by J.R. Gat and R. Gonfiantini, pp. 103-142. *Technical Report Series* No. 210. International Atomic Energy Agency. Vienna.